29302.

THE AMERICAN GEOLOGIST

A MONTHLY JOURNAL OF GEOLOGY

AND

ALLIED SCIENCES.

VOLUME XV.

JANUARY TO JUNE, 1895.

MINNEAPOLIS, MINN.
THE GEOLOGICAL PUBLISHING COMPANY.
1895.

ALFRED ROPER PRINTING CO., Printers.

St

CONTENTS.

JANUARY NUMBER.

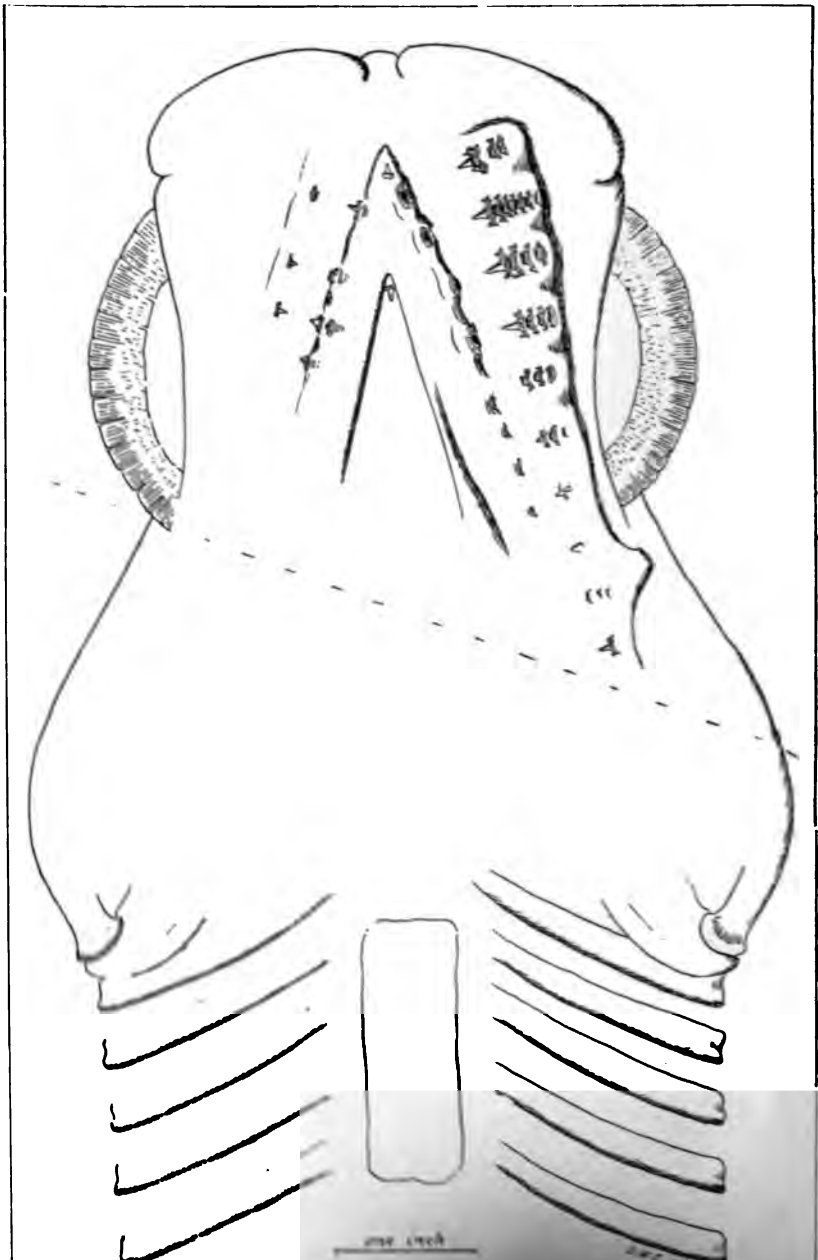
FEBRUARY NUMBER.

MARCH NUMBER.

APRIL NUMBER.

MAY NUMBER.

JUNE NUMBER.



Head of Cladodus Clarki Claypole

THE

AMERICAN GEOLOGIST.

VOL. XV. JANUARY, 1895. No. 1.

[PALÆONTOLOGICAL NOTES FROM BUCHTEL COLLEGE, No. 9.]

ON A NEW SPECIMEN OF CLADODUS CLARKI.

By E. W. CLAYPOLE, Akron, O.

(Plates I and II.)

Cladodus clarki was described in the AMERICAN GEOLOGIST for May, 1893, by the writer, from a specimen found by Dr. Clark in the Cleveland shale of Cuyahoga county, Ohio.

The specimen, though far from perfect, yet represented one of the best cladodont fossils that had up to that date been discovered and supplied characters with sufficient detail to allow specific description. Several teeth were visible in the head, but they were displaced so that their number and arrangement were not determinable. The general outline of the fish as far as the middle was fairly distinct, and the fins were so well preserved as to show almost every part of their structure above the basal elements.

Since that time Dr. Clark has found and disengaged from the matrix other specimens which enable me to redefine the species, confirming most of the characters previously published, and adding some others that were not discoverable in the former fossils.

A second specimen, also from the Cleveland shale, like the former, shows only the fore part of the fish, rather less indeed than was contained in that fossil. But fortunately the dentition is preserved in so remarkable a degree of perfection that I have no hesitation in stating that no other specimen yet described even approaches it in this respect. In spite of

its fractures, or I may say partly in consequence of them, nearly every detail that can be desired is here displayed in more or less perfection in one part or another of the slab. Owing to this wonderful condition, it has proved possible to reproduce the dentition in almost its original perfection and thus to demonstrate the resemblance, and the difference, between this long extinct genus and the sharks of our present sea, so far as the teeth are concerned.

Plate I shows the head of *Cladodus clarki* as it lies on the slab, belly upwards. The cartilages have left distinct impressions of the head, enabling us to trace them as truly as we could trace the general outline in the earlier specimen. In reproducing it for our figure, little has been attempted in restoration beyond supplying from each side what is lacking on the other or filling manifest gaps in the continuous cartilages, as for example in the gill-arches.

The excessive bluntness of the snout, which is so conspicuous in a shark, may possibly be in part due to the destruction by decay of a small anterior portion before fossilization. But the defect here, if real, is very slight, and beyond doubt the muzzle of this species was more nearly square than it was represented in our earlier figure. Its sharpness was doubtless greater in a horizontal direction, as is the case with most of the recent sharks.

The form of the nasal capsules is strikingly like that of some of the existing species. They give the conspicuous rounded outline to the front of the head and exhibit the same immense development of the olfactory lobes of the brain (rhinencephalon) as we find at the present day. They lie just in front of and below the orbits, and though crushed they do not appear to have been at all flattened out or widened during fossilization.

The Eyes. The left orbit is well preserved and shows the dermal radiating plates of the upper side of the eye, which in the fossil are somewhat displaced. Those of the lower side are concealed beneath the cranial cartilages. The right orbit retains more correctly its position in life, and for that reason it shows less of its structure, being more difficult to clear from the stone. Evidently the position of the eye was nearer to the front of the head than is now the case except in certain

somewhat abnormal genera. It had, however, the same downward look as if indicating a habit of feeding upon the ground.

The Jaws. The jaws, though much crushed, can be readily traced in spite of some amount of displacement. By the assistance of some other specimens of the same and kindred species, we are able without much difficulty to trace the outlines so far as they are preserved. The maxillaries project strongly at the sides of the head and give it its great width at that part. Within them lie the mandibles. The former are much curved in outline, the latter are more nearly straight. The condyles are fairly well preserved, especially that on the right side. They have very nearly the same form as was shown in the figure of *Cladodus magnificus*, the description of which appeared in the September number of the AMERICAN GEOLOGIST. They consist of wide flat plates of ossified cartilage, corrugated as there shown and having a similar arrangement for the accommodation of the files of teeth.

The Teeth. But the most valuable contribution to our knowledge which this fossil affords is undoubtedly, as said above, that derived from the teeth, which are admirably preserved and have been carefully exposed by the discoverer. Both their number and position can be determined with a remarkable degree of minuteness and accuracy. In fact, this single specimen places our knowledge of the dentition of the cladodont sharks in a completely new and satisfactory position.

The upper jaw on the left side of the fish is in the best condition, though the anterior portion is separated from the rest, which lies well exposed to view. On the latter part are eleven files of cladodent teeth in succession and nearly equidistant from one another. These teeth are all alike in form but differ somewhat in size, those of the anterior files being rather the largest. In the second file from the front at least seven teeth can be counted, and there are indistinct traces of one or two more. The next two are less distinct in consequence of the fracture of the stone, which is unfortunately broken slantingly across the head along the dotted line shown in the figure, and the fractured surfaces were much weathered when it was found, so that it is not now possible to restore the details over the area left blank behind the line of fracture. But on several files farther back in the mouth seven teeth can again

be counted, so that there is little room to doubt that this was the normal minimum number on one face, which number is of course much below the total.

To the eleven files of teeth on this portion of the maxillary must be added two more on the separated anterior part, composed of similar teeth, raising the whole number to thirteen: and, from a comparison with other specimens allied to this, I am induced to believe that this is the normal number and that it is seldom if ever exceeded, or, if exceeded, that the excess is small.

The teeth are all of the same general form and consist of a semi-elliptical base and a main cusp with one diverging denticle on each side, as shown in the enlarged figure. Occasionally there are traces of very minute additional denticles, and on some of the teeth the single lateral one is reduced to a very small size. The teeth are quite smooth on their flat or outer face and but very faintly striate on the rounded or inner side. They fit close against one another, the lower lying in the slight concavity in the outer surface of the one immediately above it.

It is not possible to determine from this specimen whether there was a median file of teeth in the front of the maxillary; but no evidence is found against their existence.

In the mandibles, which are in far less perfect condition, the files of teeth are less clearly traceable. Ten are visible, however, on the *left* side of the head; and there is room beside these, where fracture has destroyed the evidence, for about two more. There is also distinctly visible a median symphysial file of teeth similar to the rest, of which two may be seen in the drawing. The total number, therefore, cannot have been very different from that in the upper jaw.

Admitting, however, that there were no more that the number for which the evidence is indisputable, we have the following result: There were twenty-six files of teeth in the upper jaws, and twenty-five in the lower, making fifty-one in all; and if there were on an average only ten teeth in every file, there must have been more than five hundred teeth in the mouth of *Cladodus clarki*.

The Branchial Arches. In consequence of the crushed and broken condition of the cartilages behind the head, it is diffi-

cult and in part impossible to interpret them with much confidence. Owing to the fracture and the weathering already mentioned, nothing can be seen of the hyoid apparatus, which must, therefore, be entirely omitted. Farther back, however, can be seen manifest traces of five branchial arches. The ceratobranchial cartilages are in most cases complete on one side or the other, growing more distant posteriorly. In one or two places the connection of these with the epibranchials can be detected; but, from the position of the fish, these are for the most part concealed in the stone.

A large basibranchial plate occupies the space between the ceratobranchials, and extends somewhat behind the fifth of them. As the first and second of these are in advance of the front of this plate, it is not improbable that it has been pushed backward during the process of fossilization.

No trace of hypobranchials is visible.

The Shoulder Girdle. Amid the confusion of broken cartilages, plates and fin rays, it is not easy to be certain of details in this region. Conspicuous, however, in the midline is the coracoid plate formed by the fusion of the right and left coracoid cartilages, both of which are indistinctly seen in position. Their extensions to the scapular region cannot be positively identified, but are almost certainly represented by several fragments occupying their positions.

The Fins. The pectoral fins are the only ones that are visible in the fossil, and these are only imperfectly displayed; but by comparison several facts can be discovered. In the first place, each fin consists principally of about twenty to twenty-three strong, cartilaginous, unjointed rays, thick at the base, and becoming gradually thinner and flatter toward the margin. Most of these, excepting the few foremost, curve gently backward from their bases, then run at right angles to the body (when the fin is extended), sweeping again backward as they approach the edge. They all deploy on the edge, those in front without any membranous margin, but the hinder part of the fin possesses a distinct region that is destitute of rays, being occupied by short trichinosts.

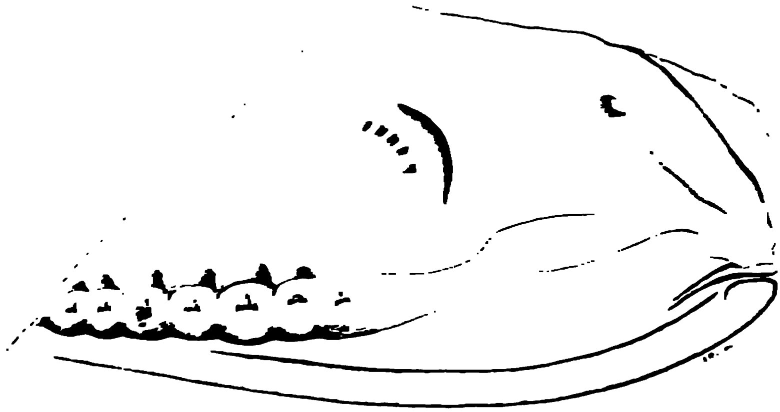
The first few rays form the front edge of the fin by running out close to one another, but behind these the rays diverge and taper on the margin: and between them come in inter-

radials, which fill the spaces thus left between the primaries. In some cases these interradials begin about the middle of the fin. These are not the rays of a second parallel series. They have no bases, but commence thin and narrow, gradually thickening and widening as they run out upon the front edge, where they attain their greatest breadth and entirely fill the gaps between the ends of the primary rays. Behind the tip of the fin these secondary rays taper to the edge, and between them occur tertiary rays, where the primaries and the secondaries do not entirely fill the intervals. These are shown in the figure.

The intercalation of these intermediate rays gives at first sight the impression of a bifurcation of the rays. But this is incorrect. There is no bifurcation. The primary rays continue single to the extremities. The five foremost ones widen out to the margin, leaving no gaps. The others behind them remain of uniform width, or even become narrower outwardly, thus affording space for the secondary and tertiary rays above mentioned. These are the most conspicuous parts of the fins, and with the aid of the figure anyone will be enabled to recognize their general character.

In regard to the basal portions, we can only regret that the crushed condition of the specimen precludes all certainty about its structure. Amid the confusion, one fragment is strongly suggestive of a primary, and another on the opposite side of a secondary, basal, from both of which the anterior fin radials may be imagined to spring. But to enlarge on such possibilities would be little more than speculation and waste of space. It is safer to suspend our judgment until a specimen or a fragment shall come to light in which the structure is well preserved, when the problem will be at once solved.

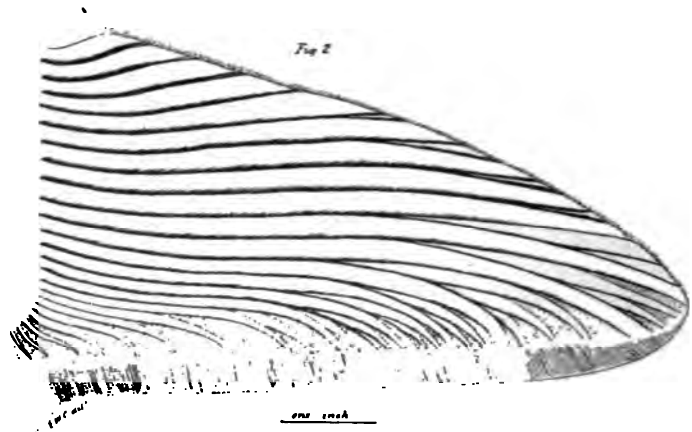
Meanwhile it is safe to say that there is no proof of an archipterygial type in the form or structure of the fin. It more resembles an ichthyopterygium closely allied in form to that of the sharks of to-day and containing the same number of rays as do many or most of these. Important differences, however, are the absence of joints in the cartilages, their great length, and the smallness of the area of the fin that is occupied by the actinosts. On all these points the specimens give positive evidence.



one inch

Fig. 1

Head of Cladodus [illegible]



one inch

Right pectoral Fin of Cladodus Clarki Claypole

CLADOD[redacted]

The second figure of the head represents a lateral view of a specimen on which, by a fortunate coincidence or accident, the fossil has preserved for us another aspect. Here the teeth are equally well shown, and the truly cladodont form of the jaw is manifest by its exact reproduction of that of *Cladodus magnificus*. Here, however, the anterior portion is missing, and nothing has been preserved behind the jaws.

Several other specimens of the same species are in the possession of the discoverer, but they at present add little to the details which have been furnished by the two remarkable ones here described, which have been excellently disengaged from the matrix by Dr. Clark.

EXPLANATION OF FIGURES.

PLATE I. Head of *Cladodus clarki*, as shown on ventral aspect, flattened.

PLATE II, FIG. 1. Side view of the head of *Cladodus clarki*, from another specimen, left aspect.

PLATE II, FIG 2. Right pectoral fin of *Cladodus clarki*, dorsal view.

THE COLUMBIA FORMATION IN NORTHWESTERN ILLINOIS.*

By OSCAR H. HERSHEY, Freeport, Ill.

CONTENTS.

INTRODUCTION.

In a recent paper,† the writer has endeavored to show that the earliest known glaciation of the northern part of the state of Illinois long preceded the epoch of loess-depositing waters and was separated from it by an exceptionally pronounced period of subaërial erosion. This deglaciation interval is marked by the excavation of extensive valleys or gorges in the limestone bed rock of the region, valleys in the old drift

*Read before Section E of the American Association for the Advancement of Science at the Brooklyn meeting, August 20, 1894.

†"The Pleistocene Rock Gorges in Northwestern Illinois," AMERICAN GEOLOGIST, vol. XII, pp. 314-323, November, 1893.

sheet, oxidation, leaching, soil production, and a general degradation of the surface of the drift, with a buried forest bed, which occurs only locally in Illinois but is more generally distributed on the Iowa side of the Mississippi river. This period of subaërial erosion was followed, in northwestern Illinois, by a period of loess deposition. As it is held by some geologists* that the Columbia formation dates from the first ice invasion of eastern North America, with a continuance of its deposition somewhat later, and also that the loess of the central and southern Mississippi valley is a portion of this formation, some doubt has been expressed that the loess of northwestern Illinois is the chronologic equivalent of that of the lower Mississippi valley. It is the aim of the present paper to show that it is so equivalent; also that there is a remarkable parallelism between the several members of the Columbia in the Mississippi embayment and in portions of northern Illinois.

In the topographic basin of the Pecatonica river, in the north central portion of this district, there is a more complete and more easily deciphered record of the stratal succession than in any other portion, and my remarks will, therefore, relate chiefly to that subdistrict. It is mostly comprised within the tract of early drift adjoining the southeastern part of the Wisconsin driftless area.†

The Columbia formation in this part of Illinois is clearly differentiated into three distinct members, which, for convenience in discussion, are designated respectively as the Florence gravel or Fluvial member, the Valley loess, and the Upland loess. These will be described under their separate headings, with discussion of their mode of formation and significance.

FLORENCE GRAVEL.

This, the basal member of the Columbia deposits, is confined to the lowest levels of the principal valleys, and its out-

*Tw[illegible] Annual Report of the U. S. Geol. Survey, for 1890-'91, Part [illegible] 462

† [illegible] Prof. T. C. Chamberlin's map of the drift-bearing areas of [illegible] States, forming plate VIII in the Seventh An. Rep., U. S. [illegible] Survey, for the relationship of the Pecatonica basin to the earlier [illegible] drift and to the driftless area of Wisconsin and the northwest[illegible] of Illinois. For maps of larger scale showing the basin, with [illegible] moraines on the [illegible] and east and the driftless area on [illegible]west, see plates xx[illegible]XXXI in the Third An. Rep., and [illegible] XXV[illegible] Sixth A[illegible]S. Geol. Survey.

crops, although fairly numerous, never exceed more than a few feet in thickness. The typical localities are in the banks of Yellow and Crane's creeks, a few miles west and south of the city of Freeport, but even here it can be examined only at low water. Wherever seen, it is in general a loose agglomeration of small gravel and sand of a blue gray color. The following section is typical of the deposit. It is commonly overlain by bluish gray loess with few shells.

1. Light blue-gray gravel and sand, with many shells. 6 inches
2. Dark blue-gray or bluish-brown fine sandy clay, full of black and light brown bits of wood............12 inches
3. Very loose light gray coarse gravel and sand, with shells and a little wood, exposed................. 8 inches

Usually the more sandy portions are full of shells of small size. A small collection of these has been submitted to Mr. C. T. Simpson, of the department of conchology, in the National Museum, who reports the presence of the following species, all of which are found living abundantly in the fresh waters of northern Illinois to-day:

Pleurocera subulare LEA.	Planorbis bicarinatus SAY.
Physa heterostropha SAY.	Sphærium stamineum CON.
Valvata tricarinata SAY.	Pisidium abditum HALD. ?

These all differ from the fossil shells generally reported from the loess along the Mississippi river.

The fossil vegetable matter is in the form of (*a*) small black particles of carbon disseminated through the deposit, and giving it its blue-gray color; (*b*) long thin fibers, apparently rootlets, many of which seem to be *in situ* in the dark sandy clays in which they now occur; (*c*) many black, semi-decayed pieces of tree branches, occasionally reaching a thickness of several inches. Some of this wood, from the same locality as the foregoing shells, was submitted to Prof. F. H. Knowlton, who reports that the interior is too much damaged by pressure to permit determination of the species, but that it is apparently coniferous. Branches have been found which certainly belong to deciduous species, but most of the woody matter from this horizon appears to be of cedar and pine.

The material of which this deposit is composed throws much light on the manner of its formation. At least nine-tenths of the pebbles in the gravel are of local material, principally Galena limestone and white chert, derived proba-

bly from neighboring bluffs. This local material is sometimes angular, but more generally is semi-rounded. Pebbles several inches in diameter have been found, and these are sharply angular. There also occurs among the gravel a great variety of drift pebbles. The sand is composed chiefly of well rounded grains of transparent colorless quartz. At one locality a gravelly stratum near the top of the deposit was lithified, by reddish brown oxide of iron, into a soft conglomerate. In the valley of Crane's creek a considerable portion of the gravel consists of fossiliferous limestone of Cincinnati age, which could not have been derived from the drift in the immediate vicinity but must have been brought by strong currents of water from the outcrop of the Cincinnati strata, several miles up the valley.

The composition, structure, and limited distribution of this member of the Columbia formation show it to be a river deposit, such as is laid down by streams of a moderate gradient at the present day. Its surface maintains a nearly constant level relative to the present water level, presumably indicating the flood-plain level of the Florence streams. This opinion is further supported by local patches, apparently similar to the alluvial soil at the surface of our present flood-plains. Now, accepting the hypothesis that the surface of the deposit represents the ancient flood-plain level, we find that this level averages 10 feet or more below the alluvial plains of the present streams. It is generally conceded that the absolute elevation of a flood-plain in any given region is directly dependent on the relative altitude of the land above sea level, the flood-plain rising if the land is depressed, and, *vice versa*, disappearing and forming at lower levels or ceasing to be a flood-plain if the land is in process of elevation. As there is no evidence supporting the supposition that the relation between altitude and water level was materially different, during the period of the growth of the Florence flood-plain, from what it is at the present day, we may safely assert that the land then stood at a *slightly* higher altitude than it does at present.

This land was also then in process of depression. The Florence flood-plain passes through the old interglacial rock gorges, which are quite numerous in the Pecatonica basin, and

in many cases fills their lower portions with a bed of blue gravel and driftwood to a depth of as much as ten feet. At the time of the excavation of these gorges the streams were more vigorous and flowed at a lower level, indicating a considerably more elevated condition of the region. But later, when the Florence gravel and alluvial sand and clay were accumulating, not only the fact of the gradual silting of the valleys, but the passage of these flood-plains through the interglacial gorges, deeply burying their rock bottoms, indicates a lower altitude for the district than formerly. It is presumed that this depression, beginning long before the appearance of the first flood-plain deposits, continued at a comparatively even rate through the Florence subepoch, and was merely the first part of the great Columbia subsidence to which the loess owes its existence.

Although this basal or fluvial member of the Columbia formation is, as yet, only known to the writer in the basin of the Pecatonica river, it is doubtless present in all the larger valleys in this portion of the state. Lying at so low a level and having such imperfect and inaccessible outcrops, it can easily escape observation. A few wells in northwestern Illinois penetrate a black mucky stratum, containing logs and other woody matter, under the loess and over the drift sheet. This occupies the same stratigraphic position as the Florence gravel, but it is rather of the nature of an upland soil than a fluvial deposit. The buried forest bed of northeastern Iowa is also stratigraphically equivalent to the Florence gravel, and the fossil contents indicate a similar climate. Although the study of the fossils of our early Columbia fluvial member is yet very incomplete, I feel certain, from the great abundance of shells belonging to species now living in this region, that the climate was not arctic, nor even such as would be found within 100 or perhaps 200 miles from the edge of the great continental glacier.

Valley Loess.

The basal member of the Columbia formation in this district grades upward into a deposit which, in the Pecatonica valley, is a moderately fine stratified sand, followed above by a light bluish gray or brown loess; but in the smaller valleys, notably the valley of Yellow creek, the loess silt immediately overlies

the Florence sand. The geographic distribution of the Valley loess is nearly coëxtensive with that portion of the district which lies lower than a plane 100 feet above the river level at Freeport. In ascending the Pecatonica river, the deposit is first met with on the north side of the valley, near the mouth of Sugar river. Here it forms a nearly level though discontinuous terrace, 50 feet above the river, and runs west along the foot of the bluffs to the Stephenson county line, beyond which it is less distinct, though occuring at intervals on both sides of the valley. At Freeport its hight has decreased to 30 feet, and northwest from there it rarely forms any prominent terrace. Wells drilled into this terrace usually penetrate about 20 feet of fine silty loess, and then 30 feet of brown stratified sand. This brown sand, or lower division of the Valley loess, is moderately coarse-grained at the base, where it often contains small pebbles and much ferruginous matter. The material gradually grows finer from the base upward, and from east to west in the valley. At the same time the stratification and lamination become less distinct as the material grows finer, and there is less evidence of wave and current action. The thickness of the deposit is something over 30 feet in the lower portion of the Pecatonica valley and decreases westward. It occurs only at the lower levels of the deeper valleys. In the vicinity of Freeport, and eastward down the valley, it has its greatest thickness below the level of 25 feet above the flood-plain of the river. Above this it thins out in passing up the sides of the valley, and it has not been recognized at hights more than 60 feet above the flood-plain level.

Throughout the Pecatonica valley from the mouth of Sugar river to Winslow, near the state line, this division of the loess maintains a nearly uniform constitution, being everywhere an easily recognized bed of brown sand. But in passing up the valley of Yellow creek we find a change, sand deposits belonging to the loess occurring only in scattered patches. Instead, we find a few feet of highly ferruginous, indistinctly laminated clay, underlying the easily recognized upper division of the Valley loess. The iron oxide was probably derived from the old soil on the ridges near by, and in some places it is present in such amount as to give the deposit the appearance of an earthy iron ore.

Its constitution, distribution, stratification, and surface configuration, seem strongly to support the hypothesis that the brown sand division of the Valley loess was formed under fluvio-lacustrine conditions, and that it consists of glacial silt derived from an ice-sheet somewhere to the east.

The lower division of the Valley loess passes into the upper division by interstratification. This latter is essentially a stratified fine sandy clay or silt, having usually either a light or dark bluish gray color; but where it has been exposed to oxidation, it has a light buff color. The lamination is very distinct in the lower portion, but becomes less so upward; and finally it totally disappears at the top of the deposit. There is also a gradual decrease in the size of the particles from the base upward, and a general thinning of the strata to the west. A few fossil shells are sometimes found in this division of the loess, apparently similar to those enclosed in the loess along the Mississippi river. Calcareous concretions are abundant in some localities, and the surface on exposure rapidly becomes coated with a whitish efflorescence. When subject to erosion, as in gutters and stream beds, the outcrop resembles laminated shales, sometimes having the appearance of being tilted at a high angle. At one place a small gully was found partially filled with rounded pebbles of a dark brown color, which, on examination, proved to be composed of loess belonging to this division.

This upper or "blue clay" division of the Valley loess is found everywhere (unless it has been removed by erosion) in the main valley of the Pecatonica river and along its principal branches in Stephenson county and in a portion of Winnebago county; but it occurs only to a limited hight above the flood-plain of the river at Freeport. It attains its greatest thickness, which is 20 feet or more, at levels less than 50 feet above this flood-plain; and thence upward it rapidly thins out, totally disappearing before the 100-foot level is reached. Hence, although it has a rather wide distribution, it is essentially a valley loess.

The phenomena connected with this division of the loess seem to indicate a formation under fluvio-lacustrine conditions similar to those of the lower division, but in a deeper and more extensive lake, with less powerful currents than that

which preceded it. That the Valley loess of this region was not deposited like the ordinary flood-plains of great rivers, is evident from the way in which the strata dip down the sides of the valleys. It was formed by the sedimentation on the bottom of a long and narrow, branching lake, of current-carried glacial silt. But the lower portion of the Pecatonica valley received a very heavy deposit which, on completion, had a nearly flat surface. This has since been extensively eroded by the stream, and a system of terraces has thus been formed.

Beyond the Pecatonica basin, along the bluffs of the lower portion of the Rock river, and at various places along the Mississippi river between Dunleith and Rock Island, quite extensive deposits of a valley loess, apparently synchronous and similar in mode of formation with that of the Pecatonica valley, have been observed. Here, also, this loess has been carved into a rough terrace system. The immediate valley of the Mississippi was largely filled up with a thick deposit of loess which may have formed a nearly level plain 50, 100 or 150 feet above the present river level. It is more probable, however, that, as in the Pecatonica valley, the surface of this valley loess, when its deposition was completed, was a shallow trough, the deposits along the bluffs being considerably higher than along the center. The Mississippi loess consists basally of an irregularly stratified bed of brown sand, gradually growing finer upward and passing through a typical loess into the weathered clay of the upland loess, which the older geologists scarcely recognized as loess.

UPLAND LOESS.

This is a bed of light brown massive clay of glacial origin, which generally conformably overlies the Valley loess. The line between them is sometimes sharp and distinct, but often the one passes into the other by insensible gradations. In the city of Freeport there is a sudden change from the blue sandy clay and quicksand of the upper portion of the Valley loess to the light brown, stiff, unweathered portion of the Upland loess. This is commonly known as "hard pan," although this name belongs more properly to another formation. It contains numerous concretions of iron oxide or limonite in the form of balls and pipes, but has no calcareous nodules. The

upper 3 to 5 feet of the Upland loess has been weathered to a loose porous clay of a buff color, which often breaks up into small cubical blocks.

The distribution of this deposit is nearly coëxtensive with all that part of northwestern Illinois west of an irregular line entering the state at the northeast corner of Stephenson county, thence running east-southeast to the mouth of Sugar river, thence west-southwest along the Pecatonica river to the Stephenson county line near the village of Pecatonica, and thence eastward to near Rockford, from which point onward it is not yet traced but is supposed to extend in a very irregular course southwestward along the valley of the Rock river to some point below Oregon, whence it probably trends off to the south, passing out of the district covered by this paper. Throughout the country between this line and the Mississippi river, the Upland loess must have originally existed as a mantle of remarkably uniform thickness resting alike on the Valley loess in the deeper valleys and the old interglacial soil on the ridges. Its altitudinal limit has not yet been determined with certainty, as it has suffered great erosion and so has been removed from many of the steeper ridges. Beds of clay which are apparently Upland loess have been observed on some of the "mounds" of Jo Daviess and Stephenson counties, and it is probable that it was originally deposited on them all. It certainly attains a greater altitude than 1,000 feet above the sea, or more than 250 feet above the Pecatonica river at Freeport.

Northwestern Illinois is a very hilly region, as compared with the central portion of the state. The range in altitude between the "mounds" and the Mississippi river is as much as 600 feet, reached sometimes within a distance of a few miles. On these steep slopes the loess remains only in patches; but in Stephenson county, where the hills attain an elevation above the valleys of only a few hundred feet and the slopes are gentler, it occupies nearly the entire surface. Perhaps more than half of the formation has already been removed by erosion, but in favorable situations nearly the entire thickness remains and is found to be about as follows: In the northeast portion of Stephenson county, and in the northwest portion of Winnebago county, 7 or 8 feet, main-

taining also about the same thickness throughout all the northern half of Stephenson county. There was apparently 10 feet of Upland loess in Freeport and its vicinity; and from here it thickens toward the west and southwest, so that it may have amounted to 20 feet in the southwest corner of the county. The thinning toward the east is in contrast with the Valley loess, and seems to indicate that the main source of the sediment lay beyond or up the Mississippi valley, instead of eastward as at the time of deposition of the Valley loess. The Upland loess is everywhere of greatest thickness in the vicinity of the Mississippi river.

A few shells have been observed in this formation at a few localities, but they are rare and not of much importance. Indeed, the loess-depositing waters in the Pecatonica and Rock river valleys must have been nearly lifeless, in marked contrast with the abundance of invertebrates in the streams of the preceding Florence subepoch.

It has been concluded from a study of the phenomena connected with the Upland loess that it was deposited under almost purely lacustrine conditions. The sediment gradually subsided to the bottom of the great lake where it was laid down with neither current nor wave action. The lake must have had a depth, over the lower portion of the Pecatonica valley, of at least 250 to 300 feet; over the Mississippi valley its depth was 600 feet or more; and throughout the greater part of northwestern Illinois it exceeded 100 feet.

The different beds or divisions of the loess of this district were deposited one after the other without any stratigraphic break between them. Their phenomena indicate that they were formed in a lake, or series of lakes, at first long and narrow, with many similarly shaped arms, and having strong currents capable of carrying coarse sand; but later gradually increasing in depth and width, with a consequent decrease in the sediment-carrying power, rising slowly along the valley slopes and over the upland ridges, until finally perhaps the highest land in northwestern Illinois was covered with water. This gradual increase in the size of the lake must have been brought on by a gradual subsidence of the land, which, as we have seen, began previous to the formation of the lowest portion of the loess.

CORRELATION WITH ADJOINING GLACIAL DRIFT.

The character of the Valley loess, as noted in the Pecatonica basin, points to an origin of its material from the lower part of the valley towards the east. As the material is undoubtedly glacial silt, we naturally look in that direction for some evidence that an ice-sheet or continental glacier lay near to the loess-depositing waters. It is now believed that such evidence has been discovered, and I will endeavor to present such portion of it as is known to me.

The irregular line mentioned as bounding the Upland loess on its eastern side very nearly coincides with the terminal line of a distinctive drift sheet.* This drift is distinguished from the very ancient sheet to the west of it by (*a*) a very much fresher appearance: (*b*) less oxidation and less depth of leaching; (*c*) a discordance between the gravel ridge (esker) systems of the two sheets; (*d*) a discordance in the direction of glacial movement, and, in the Pecatonica valley, in the trend of the terminal lines of the two ice-sheets when they occupied the same relative positions; (*e*) a very much different topography, the country underlaid by the western or ancient drift having that of a slightly glaciated region, and the country underlaid by the newer sheet having that of a more advanced stage of glaciation; (*f*) the newer sheet is several times as heavy as the old, this difference being especially conspicuous along the boundary; (*g*) the presence of slight but distinct morainic features east of the line, especially along the outer edge of the newer sheet; (*h*) very much less subaërial erosion on the drift east than on the ancient sheet west of the line; (*i*) the fact that the newer drift is near its edge overlaid by Upland loess, without any soil or other evidence of land surface between, while the drift to the west shows decided manifestations of a long interval between the formation of the drift sheet and the overlying loess.

The relations of the loess to this newer drift sheet are well shown in the Pecatonica valley. It has already been stated that the terrace formed by the Valley loess runs down the north side of the valley to about the mouth of Sugar river.

*The existence of this drift sheet, as distinct from the older drift to the west, was first pointed out to the writer by Mr. I. M. Buell, of Beloit, Wisconsin, who also noted the fact that it bounds the loess on its eastern side.

This is twelve miles farther than the terrace on the south side of the river, which does not reach the Winnebago county line. This north side terrace in Winnebago county is a well-marked bench, 50 to 60 feet above the river, which has cut into it but hardly removed much of its bulk. Directly opposite, on the south side of the valley, instead of a similar terrace of 60 feet thickness of loess, we find no loess whatever; only the sloping rock surface overlaid with thin drift of the newer sheet. It is hence evident that the loess on the north side was deposited before the drift sheet was formed on the south side of the valley, else this side would have received a heavy deposit of loess also. Having found that the epoch of loess deposition was not subsequent to that of the newer drift sheet, we will next look into the probability of its having preceded it. The newer drift in this vicinity (we use the term "newer drift" to distinguish this sheet from the very much older one to the west, and not as designating the latest formed drift sheet in America) was formed by a long and comparatively narrow lobe of the ice which projected toward the west from the general front of the glacier. There is a ridged accumulation of drift about its border, which is further distinguished by a boulder belt. But the amount of material in this ridge, especially about its western end, is remarkably small, in comparison with the length of time it was occupied by the edge of the ice as indicated by other phenomena. Had a deposit of loess been found by the ice on the south side of the valley as great as now exists on the north side, and had it plowed up and entirely removed this loess as it must have done to produce the present configuration, the morainic ridge at its border, and especially at its westward end, should now be ten times as large as it really is. We naturally conclude that there never was any deposit of loess on the south side of the valley, and that the Valley loess and newer drift sheet in this vicinity were formed contemporaneously. This conclusion is further supported by internal discordance in the stratification of the loess of the terrace as though it were subject at times to external pressure from the direction of the ice. Moreover, while the main body of the ice lobe lay on the undulating country to the south of the river valley and the north edge of the ice rested in the valley, leaving a space between

it and the bluffs in which the loess was being deposited, near its western end it touched the bluff on the north side for a few hundred yards, there accumulating its drift and boulder belt and cutting off the loess. The terrace is quite distinct east of this point, but up the valley to the west it is lower and otherwise much less prominent. This I interpret as indicating that while the loess was accumulating rapidly in the comparatively small and narrow but deep trough between the ice and the bluff east of this point, westward it spread out over the entire valley and so is less strongly developed at any given point. Had the ice not occupied the position here supposed, this would not have been the case.

The heavy deposits of Valley loess along the Mississippi river doubtless were derived largely from the ice-sheet which then stood not far back from the river in Iowa and Minnesota, and in smaller amount from its portion in Wisconsin—a northern prolongation of the ice-front here indicated in Illinois.

Just beyond the extreme border of this newer drift sheet we find the ordinary Upland loess, originally 7 or 8 feet thick. Around the northern and western sides of the Pecatonica ice-lobe the loess terminates comparatively abruptly at the edge of the newer drift. Usually, however, it overlaps it for some distance. But while it is 7 feet thick beyond the newer drift, the overlapping portion is only from 2 to 3 feet in thickness, often gradually thinning until it totally disappears. This overlapping portion may extend one, two, or ten miles back upon the newer drift, but it is usually not present in any identifiable form more than a few miles. As already suggested, there is no stratigraphic break (if the term may be applied in a matter of this kind) between the newer drift and the Upland loess. The one grades, sometimes quite insensibly, into the other.

Around the edge of the newer drift we find the Upland loess quite sandy, a feature which is rare for it away from the border, but just what we should expect near the source of the sediment, where the water rushed down from the ice-front, carrying sand as well as fine silt, and scattering it over the submerged hills near by. As a final argument, I will mention that the loess-covered country lies higher than the

country to the east, from which it is absent. This difference along the border is so great that no differential subsidence theory will explain it. To suppose that the ice advanced and plowed it up and removed it from the country where no loess is now found, is equally preposterous, for there certainly is no remnant of such a loess mantle anywhere under the newer drift sheet, nor are the slight morainic ridges which bound it at all comparable in size with those that would have been produced by the plowing up of a loess deposit, a portion of which must have escaped being carried away by subglacial and extraglacial drainage.

SEQUENCE OF THE GLACIAL HISTORY.

The sequence of events here during the Ice age, as indicated by these observations, may be summarized as follows:

1. Northwestern Illinois, after having passed through one period of glaciation, had a prolonged period of subaërial erosion and soil formation, during which the climatal conditions were probably similar to what they are to-day. Near the end of this period, but while the surface was still covered with its temperate vegetation and the streams full of invertebrate animals, we find the land in process of subsidence. The returning ice had certainly not yet reached the mouth of the Pecatonica river, and perhaps was many miles away; but the streams had begun to silt up their valleys, forming low and gravelly flood-plains.

2. Next we find the ice moving up the Pecatonica valley, the land going down towards sea level and the water level rising, producing long lake-like rivers through which the glacier-born currents rushed, carrying coarse sediment. The climate had grown cold, and the former flora and fauna had largely disappeared.

3. Still the subsidence continues; the lakes rise, and finer sediment is carried. The ice advance has, in the Pecatonica valley at least, reached its climax; and the front remains stationary, or nearly so, while the Valley loess is being deposited.

4. The epeirogenic movement has now reached its culmination; nearly the entire region, so far as not covered by the *mer de glace*, is submerged, and the Upland loess is laid down. The ice on the eastern side begins to retreat, and for a while the loess-depositing waters follow it up. But an elevatory

movement has set in, and the waters begin to subside. This movement must have been comparatively rapid, for no shore lines were formed and no considerable body of loess appears to have been laid down after the elevatory movement was well advanced.

These conclusions, although formed chiefly from a study of the loess deposits of the Pecatonica basin and surrounding region, are, I believe, generally applicable to this portion of the upper Mississippi valley. It has been held by a number of glacialists that the loess of the driftless area in Wisconsin, Iowa, and Minnesota, was laid down in a large lake produced by the ponding up of the waters through the meeting of two lobes of the ice-sheet south of that area. But it does not yet appear that ice on the Illinois side came into contact with the Iowa ice at the time required. The Upland loess, once completely mantling northwestern Illinois, west of the newer drift sheet mentioned in this paper, extends north into Wisconsin, where the waters depositing it seem to have been limited, at least for some distance in Green county, by a shore line of land instead of the border of a glacier. The same sheet of Upland loess reäppears on the Iowa side of the Mississippi, where Mr. W J McGee has shown it to be connected with a drift sheet similar to that with which it is connected in Illinois.* But on our own side of the river this drift sheet does not reach the Mississippi at the place assigned to it, if it does, indeed, at all. The earlier drift sheet of northwestern Illinois underlies all the country (except where removed by erosion) that the writer has been over between Freeport and Quincy. Furthermore, the Upland loess, which overlies the ancient drift sheet in the Pecatonica basin, is continuous (save as severed by erosion) over all the country west to the Mississippi river and south to the Rock river. It emerges from under deposits of a later age on the south side of the Green river basin, and thence continues over the country to the south as far as the writer's studies have been carried.†

*"The Pleistocene History of Northeastern Iowa." Eleventh Annual Report of the U. S. Geol. Survey, for 1889-'90.

†The relation between the loess of the Pecatonica basin and that of the central Mississippi valley was first pointed out to the writer by Mr. Frank Leverett. It has since been verified by personal observation.

CORRELATION WITH THE COLUMBIA FORMATION IN THE LOWER MISSISSIPPI VALLEY.

It is a well known fact that the loess of central Illinois is continuous with that of the extreme southern portion of the state, which is also known to be a continuation of the loess and loam, or upper member, of the Columbia formation in the Mississippi embayment. The absence of any known barrier across the Mississippi river below Savanna, Ill., the extension of loess from the driftless area to the lower Mississippi valley, the fact that the surface of the loess-depositing waters gradually rose (in relation to the land surface), at least in northwestern Illinois, and that a subsidence of the land was already in progress before the loess began to be deposited, seem to necessitate the rejection of the theory of an ice-dam to account for the Upland loess of northwestern Illinois.

We have been referring to the Upland loess as deposited in a great fresh-water lake; but it may not have been a true lake, for it seems quite probable that it had connection with the ocean waters in the Mississippi embayment.

It may be assumed that a great submergence of the land in the upper Mississippi region and a similar submergence in the lower Mississippi valley, the deposits of each of which appear to bear the same relation to the earliest drift sheet of Illinois both north and south, being apparently continuous with each other, afford sufficient evidence of the Columbia age of the loess and underlying alluvium of northwestern Illinois. Accordingly we will endeavor to show a parallelism between the various members of the Columbia formation in the Mississippi embayment and in the Pecatonica basin.

McGee divides the Columbia formation in the lower Mississippi area into four members.* The lowest member, or the Port Hudson clays, is described as "a vast bed of blue, black, gray, or brown laminated clay, commonly clean, though sometimes parted with sand, silt, or fine gravel, and often charged with calcareous or ferruginous nodules. * * * It is preëminently a low-level deposit, seldom rising far above the modern base-level. * * * This phase of the formation lines the broad ancient valley of the Mississippi from Cairo to

*Twelfth Annual Report of the U. S. Geol. Survey, for 1890-'91, pp. 392-407.

the Gulf." These clays were deposited soon after the beginning of the Columbia submergence, the great river gradually silting up its lower valley. The Port Hudson clays seem to have been formed under very similar conditions as the basal fluvial member of the Columbia in northwestern Illinois: the general appearance and constitution of the former are similar to the finer portions of the latter; and they both apparently bear the same relation to the great Columbia submergence, and to the deposits over them.

Believing that the submergence of the upper Mississippi valley was contemporaneous with that of the Mississippi embayment and the Atlantic coastal plain, I think it very probable that this submergence had reached the stage of formation of flood-plain deposits in both regions at or about the same time; and that the Florence gravel, sand, and clay of the Pecatonica basin, and presumably of all western Illinois, are the northern representative of the Port Hudson member of the Columbia formation; and that not improbably the two are continuous, as a single horizon, under the loess and modern alluvium, through the valley of the Mississippi.

McGee next finds his second member of the Columbia formation in the Mississippi embayment to consist of a coarse stratified sand and gravel (Safford's "Orange sand"). The submergence was greater and the region of the lower Mississippi had become an extensive bay, into which the great river brought vast quantities of sediment from the glaciers in the North and mixed it with the local material which makes up the great body of the sandy member in the Mississippi embayment. It certainly requires no great stretch of the imagination to suppose that the sandy or lower division of the Valley loess in northwestern Illinois may be the northern extension of this second member of the Columbia in the South.

McGee also finds that at the time of greatest submergence in the Mississippi embayment a mantle of loess and loam, composed largely of glacial rock-flour from the north, was laid down on the bottom of the great bay. At the same time of maximum submergence in the upper Mississippi valley, a very similar bed of glacial silt was being deposited over nearly all the country which was not covered with ice. This is the so-called Upland loess of the Pecatonica basin and surround-

ing region. As we have endeavored to show, there is every reason for believing it continuous along the Mississippi bluffs and to some extent over the upland country to the Columbia in southern Illinois.

In conclusion, there seems to me to be little doubt that the loess deposits of northwestern Illinois, including the Pecatonica basin, are Columbia in age. Hence it seems to be reasonably inferred that the Columbia formation does not date from the time of the first glaciation of eastern North America represented by the ancient drift sheet adjoining the driftless area in northwestern Illinois and northeastern Iowa, but was contemporaneous with an intermediate stage of glacial advance, which may probably have been closer to the end than to the beginning of the Pleistocene period.

THE MUNUSCONG ISLANDS.

By F. B. TAYLOR, Fort Wayne, Ind.

Since the autumn of 1891 excursions made in the vicinity of Mackinac island have added several new facts to those presented in a previous paper relating to that region.* But these fragments have not found a suitable place of record in other papers recently published, and they are therefore gathered together and presented here. Following this article will be another in which the Nipissing beach will be traced in its southward extension, as far as now known, and the probable limits of the lake of that time will be defined. The accompanying map is made to cover the entire width of the ancient strait of Mackinac at the time of maximum submergence. It shows details which will be referred to in the next article as well as this, and shows also the principal shore lines described in the first paper on Mackinac. The large ancient island north of Little Traverse bay is here named Traverse island.

THE MUNUSCONG ISLANDS.

From the lookout on the top of Mackinac island a long line of hills broken in two parts may be seen toward the north on the northern peninsula of Michigan. Without closer examin-

*"The H[illegible] S[illegible] L[illegible] M[illegible]" Am. Jour. Sci., III, vol. XLIII, March, 1892.

ation I had concluded provisionally that, since the summit of Mackinac was an island in the expanded waters of ancient times, the tops of those hills were also probably islands. On September 2, 1893, Dr. F. S. Pearce accompanied me on a trip

Fig. 2. Map of the Munuscong Islands and the surrounding country

to the hills mentioned and we found that there had been at least three islands and possibly more. While these ancient islands were somewhat nearer to Mackinac, they were, on the other hand, much smaller in area than I had supposed. We visited the middle or nearest one of the three. Its distance

northward from Mackinac is about 14 miles. This island was nearly three miles long, east and west, and perhaps half that width at its widest. It is irregular in outline and has a blunt spur projecting towards the north from its east end. Its longer axis extends from the east a little to the north of west and its highest point appeared to be at the west end. Another much smaller island lies about a mile and a half to the northeast and on its west and north sides has precipitous cliffs of limestone 75 to 100 feet in hight. The third island lies to the west-northwest of the middle one and on the east side of Pine river. It appeared to rise to about the same hight, but it is heavily wooded and was not visited. The middle and eastern islands form the water-shed between the nearer shore of lake Huron and the sources of the Munuscong river, which flows northeast to Mud lake, an expanded portion of the lower St. Mary's river. The high western end of the middle island is divided between the properties of Mr. Webb on the south and Mr. Brown on the north, and both slopes are cleared, although the summit is still in timber. Both sides are of steep drift, that on the north being most gradual, but reaching to a lower level. The view from the top is well worth the trip Toward the northeast are the picturesque cliffs of the eastern ancient island; and beyond in the distance, a bit of the St. Mary's river, and above that the high crest of St. Joseph island. Toward the north, stretching away from the foot of the hill is the wide, flat valley of the Munuscong and the plain of the northern peninsula. Seen from this hight, the entire sweep of low ground has the appearance of a recently deserted lake bottom. The day was clear and we could see quite plainly the hights north of Sault Ste. Marie, upwards of 35 miles to the north. St. Ignace was seen from the south bluff, and Mackinac island and the open water of lake Huron were screened only by the forest.

At the foot of the hill on the south the highest beach is strongly developed. It is the upper edge of a sandy plain sloping gradually away to the southwest. The ridges at this point are not very distinct, but there are a few low ones near Webb's house and better ones at the Italian settlement about three-fourths of a mile south. Measured by aneroid from lake Huron at Hessel, about seven miles distant, the altitude

of the highest beach is about 280 feet above lake level, and the top of the hill nearly 400 feet.

At the time of our visit, Mr. Webb had just dug a new well. The earth thrown out was composed of sand, gravel and pebbles, with a few small boulders, all very clean and nearly all well rounded. The well was sunk into the sandy plain to a depth of 32 feet, and tough stony clay was penetrated two feet at the bottom. The depth of this characteristic beach deposit is rather surprising in such a situation. It must have been entirely the work of waves that sorted the sediments out of the glacial drift and deposited them there. For when the water stood at that level there was no stream which could have been a contributor of sediments. The hill above the beach is of stony drift with a large portion of tough yellow clay. Apparently the whole mass of the beach has been gathered from drift cut out of the hill. This necessarily implies a long period of wave action. The highest beach was crossed again as we returned at the base of the hill about a mile and a quarter east of the Italian settlement. After passing nearly two miles over the top of the ancient island, first east and then south, the road descends and once more crosses the highest beach in an open wood. There are several low sandy ridges at that place, faint and broken, but lying in parallel lines on a broad gentle slope toward the south. This is the first point reached on the ancient island on going from Hessel and is a little less than four miles from that place. The road extending farther north crosses the island at a place where it was comparatively low.

Between Hessel and the middle Munuscong the marks of submergence are very plain. There are three broad terraces, two with high bluffs comparatively fresh and abrupt and each facing over a swamp on the back part of the terrace next below.

Going north from Hessel there is first a moderate rise from the shore to about 20 feet within a hundred yards. The surface is very stony and soon becomes swampy, with many fair sized boulders, apparently all glacial erratics. The ground continues with this character for nearly two miles to the foot of the first bluff, rising gradually to its base, where the hight is about 100 feet above the lake. The swamp is broken in

several places by slightly higher patches of ground, and near Hessel it is bounded by low, broken, stony ridges which have more of the appearance of glacial than littoral forms. The first bluff rises about 40 feet at its edge and 20 feet more a hundred yards back. It is composed of sandy clay with many pebbles and small boulders, except at the top, where the clay is replaced by sand.

From this the second terrace rises gradually for about a mile to the foot of another steep bluff, where its altitude is about 200 feet above the lake. It is swampy, like the back of the first terrace. The second bluff is slightly higher than the first one, and shows two feet or less of rounded gravel and small boulders overlying sandy clay with subangular stones. Back of the edge above there are signs of wave action in half formed gravelly ridges and small, low terraces. From this place the surface rises gradually northward, with some uneven features, to the last mentioned locality of the highest beach.

At another time we visited the Cheneaux islands, which lie along the shore to the east of Hessel. None of them rise higher than 50 to 60 feet above the lake. Their surfaces are generally stony. In some places erratic boulders are very abundant. Many such may be seen along the path east of the Elliott House.

It may therefore be regarded as a fixed fact that at the maximum of submergence the stretch of water between Mackinac and the Canadian highlands back of Sault Ste. Marie was broken only by the Munuscong islands. The importance of the presence of ancient islands in the area of submergence can hardly be overestimated, especially if they are situated well out from the mainland. Each one furnishes a new point of support for the restoration of the former water plane, and must prove valuable in the ultimate study of the earth's history as disclosed in the deformation of former water levels. There are many more of these ancient islands still unexplored within the basins of the upper lakes.

Gros Cap.

Two days before the Munuscong excursion, we made a visit to the high Gros Cap region which lies west of St. Ignace and borders the shore of lake Michigan. It is a flat topped, ele-

vated mass of Silurian limestone, in many respects like Mackinac, only it is not so high and is not now an island. On the hill back of St. Ignace near the public school building we found a large bed of beach gravel at an altitude of about 75 feet above the lake. About a mile out of town there is a great curved beach ridge which extends around the edge of a flat tract forming a parapet in the shape of a horseshoe. The apex of the curve points toward the north over low ground and the road crosses the ridge twice and also the enclosed hollow only a little back of the point. One can seldom find as perfect a beach ridge as this, showing so clearly by its shape and place the nature of its origin. The southward extension of the ridge on the two sides could not be seen beyond 30 or 40 rods on account of the timber. The west ridge appeared to extend south-southeast in a straight line. The altitude of this beach above the lake is about 115 feet. Its formation undoubtedly took place substantially in the following way. In the rising stage of the water the flat-topped area was covered by the waves with gravel derived from adjacent limestone cliffs which rise to a higher level. Then the whole was submerged and remained for a time as a gravelly shoal. Finally as the water fell away again the waves renewed their action, and when they began to break along the outer edge they heaped up the shifting gravel into a ridge at that place.

After crossing a swampy tract the road comes out upon the shore of lake Michigan and continues to the northwest close to the lake. For about six miles it follows a great bank of beach gravel and pebbles which lies against the base of a high limestone cliff. At several places this cliff is vertical for 50 to 80 feet and there are several picturesque outlying remnants like the "Sugar loaf" on Mackinac island. The upper limit of the littoral bank where best developed is about 45 feet above the lake, but the talus of the cliff rests upon it and obscures it in many places. Its composition, like the other beaches of this vicinity, is almost entirely of rounded pebbles of the local limestone. The quantity of beach material here is very great. The width of the bank varies from about 300 to 600 or 800 feet. The surface generally shows a

series of parallel beach ridges, in some places very distinct. This is especially the case where the bank is narrow.

The high tract of Gros Cap is divided in two parts by an east-west valley, and the shore near the lake falls away to a low, sandy flat along its front. Towards the north the high ground ends near Obeshaw's corner, and the coast beyond is lower and sandy. A road across the hill eastward from the corner affords a short cut back to St. Ignace. But a mile or more of dangerous corduroy over a swamp to the east has the effect of lengthening rather than shortening the distance. The swamp was cut off from the lake by littoral drift near St. Ignace. The top of the high ground is substantially flat and its altitude is about 160 feet. On the west edge there is a beach ridge much like that at 115 feet near St. Ignace, but not so well formed where we saw it. Much of the top is still in timber. But so far as we could see or learn by inquiry no part of it rises higher than that which we saw. Towards the southeast, Gros Cap is substantially continuous with the high irregular ground south of St. Ignace. On the northeast it is separated from high ground by a low trough one to two miles wide and occupied by swamps and ponds. The island of St. Helene, which lies about three miles off this shore in lake Michigan, is said to be a series of concentric gravel ridges. It is low, however, and probably does not attain a hight of more than 30 feet. There are many evidences of submergence along the line of the railroad northward from St. Ignace to and beyond Trout lake. But none of them appear to record the upper limit. The highest points observed were not over 260 feet above lake Huron.

Gros Cap and the other high parts near St. Ignace appear to have undergone the same severe wave action as Mackinac. They are all composed of a friable limestone which was an easy prey to the waves. On Mackinac the weakness of the rock is greatly increased by softer layers which weather into a fine fire-clay, as may be seen in the cliff south of Arch rock. When the lake stood at a higher level, this clay collected in the rock crevices of the bottom along the shore and appears there to-day as a tough, buttery deposit, perfectly smooth in the fingers, and with two colors, red and greenish gray. The

formation of the cliffs in this region has been largely influenced in some places by these weaker layers.

Mackinac Island.

Recent excursions to the low ground of the north end of the island have revealed the existence of a strong shore line there corresponding to that in the village at the south end. Its upper limit in the village is rather irregular, but the hight of the continuous beach is not far from 45 feet above the lake. The altitudes of the cut terrace and beach ridge at the north end of the island were not measured by barometer, but by an eye estimate only. In the woods near British landing, near the north end of the island, the road crosses some narrow beach ridges at nearly the same level. The road to Scott's cave branches off to the right just below this point and passes thence about a mile on the wide flat of the terrace just mentioned. At its back the flat ends against the foot of a steep bluff, which, for much of the distance, is a rock cliff 30 to 40 feet in hight. Its strength and altitude prove it to be the same shore line as that in the village. The littoral origin of this terrace and cliff is fully proven by Pulpit rock, which stands on the terrace a few rods out from the foot of the cliff. It is a tall and very slender outlier of fragile limestone which happened to be left standing when the waves finally withdrew. Its feeble structure, on the one hand, suggests an ultimate limit to the time since it was left standing, and its distance from the cliff, on the other hand, suggests the relatively long duration at one plane of the wave action which made the cliff and a large part of the terrace. The marshy little valley back of British landing was probably shut in by a spit made at the same time, and with material derived mainly from the Scott's cave cliffs. Modern wave action has removed all that may have existed of this shore line along the east and west sides of the island.

This strong shore line on the north and south ends of Mackinac island, at St. Ignace, and Gros Cap, appears again at McGulpin's point across the straits. A similar beach at half its hight appears also on the shores of Little Traverse bay. The character and position of this shore line agree in all respects with the Nipissing beach as identified at points farther north, and it has been so named on the map. The

features shown on the shores south of the straits were most of them described in the earlier paper on Mackinac referred to above, and those at Wellsburg and Sault Ste. Marie were also described in a previous paper.* At the maximum of submergence the ancient strait was 75 to 80 miles wide between the beach at Root river in Canada and the mainland on the south.

Since the publication of the first paper on Mackinac new measurements of the hight of its upper beaches had led me to suspect that I had made them a little too high. But I have learned that recent instrumental leveling by the military authorities makes the beach back of the parade ground 175 feet above the lake. This is five feet higher than I had made it, and substantially confirms my first measurement. The same authorities make the top of the big gravel ridge behind the village 60 feet above the lake. This is about 15 feet higher than the Nipissing beach near the Grand Hotel and the Mission House, and can hardly be considered as a part of it.

The northward rise of the highest beach from Mackinac to the middle Munuscong island is at the rate of a little more than five feet per mile, while the rise from the latter place to the Root river beach north of Sault Ste. Marie is a little more than four feet per mile. This is a good illustration of the value of ancient islands in disclosing terrestrial deformations which could not be detected otherwise.

A wider experience in the study of deltas has led me to suspect that my early estimate of the altitude of the highest beach at Traverse City was probably placed a little too high. The estimate of 80 feet was based on the hight of the old delta of Boardman river. I have not had an opportunity, however, to re-examine it.

Comparison of Shore Lines.

The following is a tabular statement of the hights in feet of the principal shore lines within the area of the map:

Highest Beach.

	Above sea level.
Root river, near Sault Ste. Marie (Lawson)	1,014
Wellsburg	910+?
Middle Munuscong island	860
Mackinac island	785

*"A Reconnaissance of the Abandoned Shore Lines of the South Coast of Lake Superior," American Geologist, vol. XIII, June, 1894.

Wequetonsing and Petoskey	....	680
Traverse City	..............probably a little less than	660

NIPISSING BEACH.

	Above lake Huron.*
Sault Ste. Marie	70
Mackinac, St. Ignace, Gros Cap, and McGulpin's point	45
Wequetonsing and Petoskey	25

Besides these, there are isolated ridges and terraces at intermediate levels, but as yet no certain correlation of these at different places has been made out.

These notes make the record of observations so far made by me in the basin of the upper Great lakes substantially complete; and this is the sixth of a series of papers in which they have been published. On each of the principal excursions from twenty to sixty photographs were taken of the features observed. The plates used were 6½ by 8½ inches. Many of the pictures are good, although few views of the best sort could be obtained on account of the rough and uncultivated condition of the country.

THE AGE OF THE GALENA LIMESTONE.

By N. H. WINCHELL, Minneapolis, Minn.

[Read at the Brooklyn meeting of the American Association for the Advancement of Science, August, 1894.]

From the time of Schoolcraft, who, in 1820, assigned the lead-bearing beds of the upper Mississippi to the Subcarboniferous, until now, the Galena formation has been a subject of much difference of opinion. W. H. Keating thought all the magnesian limestones of the upper Mississippi valley belonged above the Coal Measures, and made them the parallel of the Lias of Europe. Owen showed that they pass below the Coal Measures, and at first (1839) classified the lead-bearing beds with the Cliff limestone of Ohio, which was admitted to be of the same age as rocks which in New York state were of the Upper Silurian. Locke went further, and made out a fair case by placing the underlying beds, which now are generally admitted to be of Trenton age, as the equivalent of the Blue limestone of Ohio, which was then also supposed to be of the

*Add 581 feet, the mean hight of lake Huron, for hights above the sea.

age of the Trenton. The intervening strata as known to exist in New York, i. e., the shales and limestones of Pulaski and Lorraine, etc., were not found. James Hall at first accepted the opinion that the Galena should be put in the Upper Silurian, as an equivalent, or a part of, the Niagara limestone. In 1843 T. A. Conrad stated, on the evidence of fossils furnished him by Mr. J. N. Nicollet, that the Galena belonged in the upper part of the Trenton. In 1852, however, Dr. D. D. Owen, in his final tabulation of his results of the survey of the region, came to the conclusion that the Galena limestone is the western representative of the Utica slate and the Hudson River formations of New York, the strata immediately underlying being named "St. Peter shell limestone," or Formation No. 3, and supposed to represent the Trenton. This was nearly in accord with Prof. Hall's later view that the underlying strata, with greater or less distinctness, represent, largely by paleontological resemblance, the Birdseye and Black River limestones. While the terms Blue and Buff, which have had varying fortunes, and questionable value, have remained, in one form or another, as designations for the underlying limestones, there has been no disturbance of Mr. Conrad's general conclusion that the Galena is of the age of the Trenton, indorsed as it was by Hall and Whitney in 1870, until 1879, when C. D. Walcott revived the idea of its representing the Utica slate,* and fortified it with evidence drawn from a comparison of the fauna of the Utica slate with that of the Galena. He also shows the extension of the fossils of the Utica into the Hudson River above and the Trenton below.

Until now there has been no published investigation into the paleontology of the Galena since that of Mr. Walcott. It is the purpose of this paper to show that Mr. Walcott's conclusion can hardly be accepted.

Mr. Walcott surveys the question both stratigraphically and paleontologically. In the former survey he reaches the result that a general, widespread change in the nature of the sediments took place at the close of the Trenton, extending from New York to Tennessee and further southward. In Illi-

---

* *The Utica slate and related formations. Fossils of the Utica slate, and metamorphoses of Triarthus becki.* C. D. WALCOTT. 1879, Albany. Printed in advance of vol. x, of the Transactions of the Albany Institute. June. 1879.

nois this change is shown by the sudden transition from the Trenton limestone to the Thebes sandstone. There might be added to this general truth a further general law which pertains to the Lower Silurian in North America, viz., that the Utica slate is followed by the Hudson River by a very gentle change, or is merged into the Hudson River so closely that the two formations cannot be separately identified in numerous places. Thus, Safford shows that in Tennessee the Nashville (Hudson River) involves the Utica slate. Although the slate is lithologically a dark shale, 100-150 feet thick, the characteristic graptolites are not confined to this stratum, but run up into the main body of the shale, and are found at numerous localities. Lithologically the Utica slate and the Hudson River formations usually are lost in each other, being linked together in all descriptions, their fossils even being put into the same chapter by James Hall in 1847. There is hardly an exception to this close union of the Utica slate with the Hudson River; indeed, as Mr. Walcott truly remarks, at the opening of his paper, the term Hudson River, with the Utica slate as a subdivision, has been generally received into geological literature.

In summarizing the paleontological data the following table is given by Mr. Walcott:

	Utica	Galena.
Total number of species	100	78
Species limited to the formation	54	19
Species limited to the formation and the Trenton group	11	29
Species limited to the formations and the Hudson River formation	11	3
Species common to the Trenton, Hudson River, and Utica and Galena formations	24	27
Species passing from the Trenton to the Utica and Galena	35	56
Species passing from the Utica or Galena to the Hudson River	35	30

Of the 35 species, however, which pass from the Trenton to the Utica 10 are hardy species, ranging from the Chazy and Black River to the Utica. There is no way of telling, from Mr. Walcott's table of the fossils of the Utica slate (pp. 34-38), what part of the 56 species passing from the Trenton to the Galena had their commencement below the Trenton limestone.

It may be assumed therefore that of the 100 species known in the Utica 25 originated in the Trenton, and of the 78 species known in the Galena 56 originated in the Trenton or in a lower horizon. According to that the ratios of alliance may be expressed thus:

Ratio of Trenton species found in the Utica, in all parts of the country, 25 per cent.

Ratio of Trenton species found in the Galena, in the upper Mississippi valley alone, 70+ per cent.

The table therefore shows a closer alliance of the Galena with the Trenton than of the Utica with the Trenton. Mr. Walcott remarks:

> The table shows a greater change took place in the fauna of the Utica slate than in that of the Galena limestone, the former having fifty-four species limited to its boundaries, and thirty-six derived from the Trenton; while the latter has nineteen species peculiar to it, and fifty-six passing up from the Trenton formation beneath.

Mr. Walcott's data therefore, in this respect, do not strongly support his own conclusion as to the occurrence of a break at the top of the Trenton, separating it from the Galena. On the contrary his data would seem to indicate a strong connection between the Trenton and Galena. When it be considered further that he adduces no evidence whatever of a lithological change at that horizon, in the region of the Upper Mississippi, but that all his quotations bearing on the top of the Trenton are descriptive of the passage to the Utica slate in other portions of the country, or, when they apply to the Trenton of the Upper Mississippi, they testify to the slowness of the change from the Trenton to the Galena, it appears that the conclusion announced is hardly supported by the evidence adduced.

Recent work on the rocks of the Lower Silurian by the Minnesota Geological Survey has brought to light numerous adverse facts bearing on this question, which, put against the paucity of affirmative evidence adduced by Mr. Walcott, lay at rest forever all uncertainty of the age of the Galena limestone. Messrs. E. O. Ulrich and Charles Schuchert have co-operated with the writer in studying the paleontology of the Lower Silurian in the Upper Mississippi valley. The information in detail will appear in vol. iii of the final report of the survey, now in press. It is sufficient here to give a part

of the summarized facts, so far as they bear on the age of the Galena limestone.

It was found that the Galena limestone changes gradually toward the north, by acquiring shale. While this seemed to pervade the entire limestone mass by the interbedding of scattered thin layers of shale at irregular intervals, yet it is most apparent, perhaps, near the bottom, where shaly characters take the place of calcareous ones, on the same horizontal plane. Therefore as a lithological horizon there was no dependence to be placed upon it. It was found, also, that the fossils which had been said to be characteristic of the Galena limestone in Iowa, occurred in some shales underlying the limestone. Paleontologically, therefore, the Galena limestone had not definite downward limitation. In this absence of positive stratigraphic characters, it became necessary, if the term be worthy of preservation, to assume a horizon in the midst of the shales, below which the term Galena might not extend. This lower limit was chosen at the lowest position at which the characteristic fossils, named by the authors of the term, were known to occur. Such fossils as *Ischadites iowensis*, the sunflower coral of the lead region, and *Clitambonites diversa* have here their first appearance. They are associated with an increased abundance of *Zygospira recurvirostra*, and with several species of *Nematopora* and *Arthoclema*. At this horizon also occur *Rhynchotrema inequivalvis*, *Orthis pectinella* (var. *sweeneyi*) and *Pholidops trentonensis* (var. *minor*). Here also are found several species of *Strophomena*, viz, *billingsi*, *schofieldi* and *emacerata*. Here was found a new species, *Orthis meedsi*. Several others which are found first at lower horizons, occur here, apparently, in increased numbers, viz., *Rauffella filosa*, *Cylindrocœlia minnesotensis*, *Diastoporina flabellatum*, and *Mitoclema mundulum*.

Owing to the progressive change, both vertically and horizontally, from limestone to shales, in passing northward from the typical region of the Galena limestone, it cannot be said that the foregoing paleontologic characters will everywhere be found at any set lithologic horizon. But as an average, for the southeastern part of Minnesota, it is probably true to say that the base of the Galena formation is found to occur about 30 feet below the lowest distinctively dolomitic beds. Toward

the north this interval of 30 feet might become 50 feet, or the overlying limestone might entirely disappear, while toward the south it dwindles and disappears, allowing the base of the Galena limestone proper to approximate the lowest limit of the characteristic fauna.

While the foregoing indicates an intimate connection between the Trenton and the Galena, a closer examination of the faunas which are found above and below this arbitrary line, throws still more evidence on their alliance. A preliminary partial tabulation of the results of our study appears below.

HUDSON RIVER, GALENA AND TRENTON FAUNAS.

CLASSES.	Total Lower Silurian Genera.	Total Lower Silurian Species.	TOTAL SPECIES. (With varieties.)			SPECIES BELONGING TO TWO PERIODS.		
			Hudson River.	Galena.	Trenton.	Hudson River and Galena.	Galena and Trenton.	Hudson River and Trenton.
Sponges	7	8	2	5	5	....	2	....
Graptolites	2	3	2	1	....	....	....	....
Corals	5	10	2	1	7	....	....	....
Bryozoa	48	145	1	58	119	....	19	....
Brachiopoda	25	73	27	43	37	5	11	1
Lamellibranchiata	27	113	18	41	60	....	1	....
Ostracoda	22	62	6	15	49	....	1	1
Trilobites	21	32	7	23	15	4	8	2
Totals	157	446	65	187	292	9	43	4

It appears therefore that forty-three species are known to be common to the Trenton and the Galena, in Minnesota, and but nine common to the Galena and the Hudson River, four of those nine being such hardy species as to survive from the Trenton to the Hudson river. This indicates that if the break which has been found by Mr. Walcott to prevail so widely over the country, separating the Trenton from the Utica slate, be sought for in the northwest, it cannot exist between the Trenton and the Galena, but must be looked for at a higher horizon.

Prior to Mr. Walcott's generalization it had been customary to place the possible Utica horizon with the shale overlying the Galena, i. e., in the Maquoketa. Prof. James Hall called attention to a certain black shale at the base of the Maquoketa, in Iowa, in 1858, as the probable western representative

of the Utica slate,* remarking that the presence of Lingula of a large and a small species, enhances the resemblance. Prof. J. D. Whitney, in reporting on the lead mines of Wisconsin† in 1862, dwells at length on the carbonaceous character of the Hudson River shales, which are said to show sometimes "faint graptolitic markings."

"The presence of carbon in the shales of the Hudson River group over so extensive an area, and in such large quantity, is a matter of considerable interest, both practically and scientifically; it seems hardly possible that a material existing in such abundance and containing from one-tenth to one-fifth its weight of bituminous and carbonaceous substances, should not at some future time be utilized for lighting or heating purposes, in a region where coal does not occur," p. 184.

The suggestion that the Utica slate horizon is to be sought for in the beds overlying the Galena is confirmed by later developments in the oil regions of Indiana and Ohio where the Utica slate is recognized at the bottom of the Hudson River formation, and yet where the underlying "Trenton" is a porous dolomite, not unlike the Galena limestone. In fact it has been found that in many cases the fossils which in the upper Mississippi valley are found in the Galena, in Kentucky and Tennessee are said to come from the Trenton limestone.

It may therefore be considered that the Galena limestone is only a phase of the Trenton, intensified in the typical region, and fading out in all directions. It is a convenient designation in Iowa and some parts of Wisconsin and Illinois, but in Minnesota its convenience hardly warrants its continued use. The physical break and the faunal change which follow it, in the Northwest, are the probable parallels of those which mark the transition from the Trenton to the Hudson River (Utica slate) horizon to which Mr. Walcott has called attention.

May 5, 1894.

ACIDIC ERUPTIVES OF NORTHEASTERN MARYLAND.

By Charles Rollin Keyes, Jefferson City, Mo.

For several years prior to his peculiarly sad and untimely death, a few months ago, the late professor George H. Wil-

*Geology of Iowa, vol. I, part I, p. 67, 1858.

†Report on the Geological Survey of Wisconsin, vol. I, James Hall and J. D. Whitney, 1862.

liams had been rapidly gathering materials for a systematic work on the massive rock types of North America. Preparatory to this special attention had been given to the eruptives of the Piedmont plateau, particularly in Maryland. Carefully made field and petrographical studies were instituted in different areas. Some of the results had already been published.* Two other memoirs were in press, both by the U. S. Geological Survey; one on the old volcanics of South Mountain (which, however, is out of the district just named) by Dr. F. Bascom, and the other on the granitic rocks of Maryland by professor Williams and the writer. Still other results were nearly ready for presentation.

As a part of the work outlined there has recently appeared the *Granites of Cecil County in Northeastern Maryland*,† by Dr. George P. Grimsley. It is to some points brought out in this contribution to Maryland geology that attention is directed.

The rocks under consideration are the granite-gneisses which are widely known as the Port Deposit granites. They are regarded as igneous in origin, though now more or less squeezed, but the proofs of their eruptive character need not be reiterated here. The area is an extensive one and takes its name from the town of Port Deposit, in the neighborhood of which are large quarries. From them a large amount of stone has been shipped to nearly every part of the United States. The rock itself is admirably exposed for a distance of fully ten miles on both sides of the stream. The stone is a light colored, somewhat gneissoid, biotite granite, which is rather coarse grained but seldom shows a porphyritic facies. A more or less distinct banding of the light and dark constituents is quite characteristic. Both observations in the field and microscopical examinations of thin sections indicate clearly that the parallel arrangement of the components has been secondarily acquired through enormous pressure.

The area is bordered on the north by trappean gabbro, on the east and west by the Piedmont gneisses. The area is divided medially by the Susquehanna river, which has cut a

*Williams: U. S. Geol. Sur., Bul. 28. Washington, 1886. Also AMERICAN GEOLOGIST, vol. VI. pp. 35-49. Minneapolis, 1890.

†Jour. Cincinnati Soc. Nat. Hist., vol. XVII, pp. 59-67 and 78-114. Cincinnati, 1894.

wide, deep gorge into the massive crystallines of the region, extending from beyond the state boundary nearly to the mouth of the stream. For the greater part of the distance the river flows in a canyon-like course from 250 to 300 feet below the general level of the Piedmont plain. The high cliffs and salients of granite stand out prominently on either side of the water course and form conspicuous features of the picturesque valley.

Under the microscope thin sections of the granite from Port Deposit show a more or less distinct parallel arrangement of the minerals. The quartz is broken and granulated, the biotite is not so abundant as in some of the other Maryland granites; microcline is of common occurrence; epidote and muscovite are developed in many places from the feldspar: while small dark colored garnets are not of unfrequent occurrence.

The granite is cut through in a number of places by dioritic dikes which vary in width from a few inches to 400 or 500 feet. Contrary to what has been commonly supposed to be the case, the southern part of the area is more gneissic than the northern. Consequently the Port Deposit rocks, which may be properly regarded as gneiss, pass by gradual transitions into the massive granite of Rowlandville, which lies to the north. Another feature which has been observed is that as the granite approaches the gabbro area there is a greater and greater development of the ferro-magnesian minerals, until at the contact it often becomes exceedingly difficult to determine whether the rock is really a granite or a gabbro. Another notable characteristic of the granite is the presence of numerous basic secretions, which often have the appearance of rounded inclusions.

Two types of granitic rocks have been mentioned. The one is near Rowlandville and the other in the neighborhood of Port Deposit, the latter being the more gneissic. In the former the rocks have been not sufficiently squeezed to entirely obliterate the original characters. They do, however, show in a remarkable manner the effects of orographic pressure which has changed both the constituents and the structures in a very interesting way. One of the most prominent metamorphic changes in the rock, as fully emphasized by Dr.

Grimsley, has been the extensive development of epidote. As stated by him, the physical conditions particularly have been exceptionally favorable to the formation of this mineral. It occurs everywhere in the Rowlandville area as a prominent metamorphic product, assuming variety of forms, sharply outlined crystals, rounded grains and hair-like needles, and developing in all of the original constituents alike. The production of epidote to such an unusual degree is manifestly one of the chief results of the metamorphic action, and hence the consideration of the mineral has been given in full detail. Now, the original Rowlandville rock was evidently a normal granitite or biotite granite having the common hypidiomorphic structure and carrying unusually large proportions of plagioclase. In places it is thought that it may have also contained some original muscovite. As already stated, epidotization has been carried on on an extensive scale. It is most marked in the feldspars. In the perfectly fresh rocks, those which have suffered no effects through meteoric changes, the formation of the mineral, it must be admitted, must certainly be metamorphic rather than the result of weathering, as has been stated from time to time. All degrees of replacement of the feldspar by epidote occur, from crystals in which only an occasional grain of the latter mineral has originated to those in which almost complete pseudomorphism has taken place. Whenever there is a small amount of epidote, crystals of this mineral, with sharp outlines and of the usual monoclinic habit, are of frequent occurrence; but as the amount increases the different crystals unite into larger masses with irregular boundaries. Another interesting observation which was made concerning the Rowlandville granite was that the epidote had no special tendency to develop in or near cracks in the feldspars, but that whenever the latter crystals showed pressure effects little or no epidote was formed. Another suggestive observation is that the epidote frequently developed in certain zones in the feldspar crystals, in many cases both the interior and exterior of the feldspars remaining unchanged. Considering the well known fact of zonal variations in the chemical composition of feldspar crystals which has so well been worked out both by Höpfner* and by Becke,† who

*Neues Jahrbuch, Geol., Min. u. Pal., 1881, 2 Haft, p. 182.

†Tschermak's min. und petro Mitth., XIII, Band, p. 414, 1893.

have proved that zonal feldspars, as a rule, grow more basic towards the center and that there is sometimes a recurrence of a more basic zone within the more acid layers, and remembering that the plagioclase feldspars in the Rowlandville granites are made up of different mixtures of the albite and anorthite molecules, the formation of the epidote may be attributed to a particular chemical composition of a portion of the feldspar which has been brought under favorable physical conditions. It may thus be concluded that under certain conditions and with certain combinations of the albite and anorthite molecules there was a special tendency towards epidotization, when the rock underwent metamorphic changes arising from great pressure.

It is an excellent illustration of one of those nicely balanced or delicately poised cases which are met with occasionally in the petrographical study of rocks which have been influenced by crustal movements, and of a change which is to be expected in a region which perhaps represents a part of the denuded base of an old mountain range. It is but the expression of the universal law that in stony aggregates the whole mineralogical composition and structure are being modified continually; in some places slowly, and others more rapidly according to the attendant circumstances. The ever changing physical conditions invariably set up continuous molecular shiftings in every rock, whatever may be its composition or its relations. Of recent years it has come to be more and more clearly understood that the changes undergone by rock masses have been occasioned by the natural tendencies of minerals to assume combinations more stable from those less stable. Wadsworth* in particular has emphasized this point. But the statement has not carried with them its full import and meaning. For, in any particular case while there is an attempt towards adjustment to satisfy a certain set of conditions, the conditions themselves continually change, sometimes in one direction, sometimes in another. In the production of these alterations in rock-masses time does not enter necessarily as a factor, although ordinarily the older a rock is the greater is the chance for disguising its primitive character. Thus in attempting to determine the original condition under

*Nature, vol. xxxv, p. 417, 1887.

which, for instance, an eruptive rock has solidified, the problem becomes more and more difficult in proportion to the amount of change, until finally a point is reached where it is absolutely impossible to say with certainty what the real nature of the stony mass was in the beginning.

In the consideration of the wide-spread effects of regional metamorphism the agency of tangential pressure as the result of orographic movements is by no means the least important. Since the appearance of the classic work of Heim† the influence exerted by this one factor has become more and more clearly understood, as may be inferred from the writings of Bonney,‡ Hatch,§ Lehmann,‖ Reusch,¶ Törnebohm,** Schmidt,†† Teall,‡‡ Williams§§ and others.

But to return to the epidote belts in the plagioclase crystals. Dr. Grimsley also remarks that the undoubted causal relation which exists between the zonal structure of the feldspars and their alteration whereby those zones richest in lime have been most completely changed to epidote, greatly favors the opinion advanced. This view also finds substantiation in other granitic areas and probably furnishes a key to the problem of why similar rocks through metamorphism and under apparently the same physical conditions change to very different masses. It is probably a principle of very wide application and one which will doubtless furnish a clew to many questions concerning metamorphism which have been long re garded enigmatical.

With the Port Deposit rock, which, like the Rowlandville variety, is in all probability of the eruptive origin, there is a very distinct foliated structure that has been produced sec. ondarily through pressure. The result of more intense dynamic action has been to crush the minerals, thus giving rise to cataclastic rather than mineralogical changes, as epidotiza-

†Untersuch. über den Mech. der Geb. u. s. w., Band II, 1878.

‡Quar. Jour. Geol. Soc., London. vol. XLII, 1886.

§Tschermak's min. und petrog. Mitth., Bd. VII. 1885.

‖Undersuch. uber die Ent. der altkry. Schiefergesteine, u. s. w. 1884.

¶Neues Jahrbuch, BB. V. 1887.

**Geol. För. Stockholm Börhandl., V. 1880.

††Neues Jahrbuch, BB. IV. 1886.

‡‡Geological Magazine, Nov., 1886.

§§U. S. Geol. Sur. Bul., No. 28, 1886; also ibid., No. 62, 1890.

tion. The feldspars of this rock are both alkaline and lime-soda varieties, with a marked development of potash feldspar in the form of microcline. The feldspars show conspicuously the effects of great squeezing and crushing, which, combined with the same chemical alteration, have given rise to a considerable development of the albite mosaic.

The Port Deposit granite-gneiss carries a considerable amount of allanite which is invariably mantled by epidote, the two forming isomorphous intergrowths. The epidote thus formed is regarded as original, as has been thought probable in the case of similar occurrences in the granites farther south in the vicinity of Baltimore.

In regard to the staurolitic mica schist which forms a long narrow belt separating the Rowlandville and Port Deposit areas, Dr. Grimsley is inclined to the view that it was originally a sedimentary deposit, more ancient than the granites and that it probably owes its highly crystalline character to contracting metamorphism produced by them at the same time of their eruption.

Attention is called in the memoir to the economic value of the Port Deposit rocks, but more on this point might have been said. The quarries furnish about one-half of the entire amount of granite obtained in the state of Maryland. The stone has been taken out in commercial quantities for more than three-quarters of a century. The output of the Port Deposit quarries alone during 1892 was nearly eighty thousand tons, valued at almost half a million of dollars. As a building stone it is very durable, and according to the test made by the United States engineers it withstands a crushing strain of over eighteen thousand pounds per square inch.

Among the structures built of this rock, as may be gleaned from the Maryland hand-book, may be mentioned fortress Monroe and the artificial island opposite it on which was erected fort Wood, forts Carrol and McHenry, near Baltimore: fort Delaware, the sea-wall at St. Augustine, Florida; the navy yard and dry dock at Portsmouth, Virginia: the Naval Academy at Annapolis, Maryland: the foundation of the Treasury building, the Philadelphia, Washington and Baltimore railroad stations and Saint Dominick's church at Washington, also the bridges over the Susquehanna at Havre de Grace.

Maryland; the Chestnut street, Girard avenue, Callowhill and South street bridges over the Schuylkill at Philadelphia; the principal bridges of Baltimore, and the new water works crib at Chicago. It has also been used in construction of the entire plant of the Maryland Steel Company's works at Sparrow Point, Maryland, and of Harveford college; besides a large number of private dwellings and public buildings in Baltimore and Philadelphia.

EDITORIAL COMMENT.

State Academies of Science.

The fact that the general government lends substantial aid in furthering scientific research is very generally acknowledged to be simply a wise provision for promoting the general welfare and happiness of the entire people. From this point of view the maintenance of organizations for the investigation of problems relating to astronomy, geology, mineral resources, coast and geodetic surveys, irrigation of the great arid wastes, chemical and lithological phenomena relating to agriculture, sanitation and public health, and other matters that affect more or less the entire public, is recognized as nothing more than the discharge of an imperative duty. That the individual States also have duties in relation to similar problems has not been so generally recognized. Most of the States support universities where, in addition to the work of teaching, a greater or less amount of scientific work is done. Many have technical schools under one name or another, but these, like the universities, are founded not so much for research as for purposes of instruction. In a few states geological surveys are supported; but, as a general rule, States, as such, have rarely done much in encouraging scientific work.

Notwithstanding the indifference of the public to scientific work as expressed by the local state governments, nearly every State in the Union contains a number of capable men devoted to scientific research. The recognized advantages of organization and coöperation, as compared with the results of disconnected individual effort, have led to the fo[illegible] State-

Academies of Science; so that now there is scarcely a State in the Union which has not its organized band of enthusiastic laborers in the various scientific fields. These State Academies have some advantages over the larger national associations, not the least important of which is the fact that attendance upon their meetings involves less expense of time and money: two commodities which the unselfish scientific worker can usually illy afford to spare. Some of the best work done anywhere is presented at these meetings. Like all other truly scientific work it enlarges the domain of human knowledge, brings the forces and phenomena of nature more directly under human control, and ameliorates in some degree the conditions of human existence. The public, which, without effort on its own part, immediately becomes possessed of all the benefits of scientific investigation, owes something to these scientific workers.

A few States discharge, in part, their obligation to the people on the one hand and the scientists on the other by publishing and distributing the reports of the local Academy. The reports of the Kansas Academy have for some years been published by the State. Three years ago Iowa began the publication of the reports of her Academy. It is to be hoped that the same relation between the state organization that embodies the highest scientific attainments and the state government will be established in more and more of the intelligent commonwealths of the Union.

In this connection it is a matter for congratulation to find that the members of the Indiana Academy and the more progressive members of the recently elected legislature of the same State are planning to effect an arrangement whereby the work of the Academy may become available for the information of the people at the trifling expense of publication and distribution. The Indiana Academy has now been in existence some nine years, and in that time has enrolled among its members many workers of more than national prominence. Amony these the reader will easily recall Jordan, Coulter, Branner, Mendenhall, Arthur, Noyes, and others no less eminent. While the Academy, as such, has published little directly, its papers have embraced the results of some of the best work covered by the period of its existence. Quite re-

cently it has undertaken a thorough Natural History Survey of the state, a task which, by reason of its numerous well scattered and thoroughly competent observers, it is able to accomplish much more cheaply than any other organization. Let us hope that the coming legislature of this wealthy and intelligent State will recognize its opportunity. S. C.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Thirteenth Annual Report of the United States Geological Survey, for the year 1891-'92. J. W. POWELL, Director. Part I, Report of the Director: pp. vii, 240, with two maps; 1892. Part II, Geology, accompanying papers; pp. x, 372, with plates III-CVII, and 41 figures in the text; 1893.—Part III, Irrigation; pp. xi, 486, with plates CVIII-CX, and figures 42-63 in the text; 1893. Each of the three parts of this report, which was published a few months ago, forms a separate volume, and each has its own index. While some delay is unavoidable in the issuance of these important reports, it certainly seems very desirable and practicable to diminish considerably the interval between the work and its publication. It is very gratifying in this connection to note that only half a year intervened between the times of distribution of the twelfth and thirteenth annual reports of this survey.

In the first part Maj. Powell and the heads of the thirty-two divisions of the survey present their administrative reports, briefly stating the areas of exploration, special subjects under investigation, and the progress of topographic and geologic mapping. During the fiscal year of this report, topographical surveys were being made in twenty-three states; and previously these surveys had been finished in Massachusetts, Rhode Island, Connecticut, New Jersey, and the Appalachian mountain belt from Maryland to Alabama. The geological mapping up to the date of this report had included the western two-thirds of Massachusetts; a large area from Baltimore south to Richmond; another in the Appalachian region of eastern Tennessee, northwestern Georgia, and northeastern Alabama; small tracts about Madison, Wis., in eastern Iowa, the northwest part of South Dakota, in Florida, about New Orleans, in central Texas, and about Denver and Leadville in Colorado; larger areas in New Mexico, northern Arizona and southern Utah, the Yellowstone National Park, and a contiguous region reaching north and northwest in Montana; small districts in Washington and about Eureka and Virginia in Nevada; and a large region of the Sierra Nevada belt through the northern two-fifths of California. Final geological surveys, of greater or less extent, had been completed in thirty-two states and

territories, covering an aggregate of 110,000 square miles, and represented by a hundred atlas sheets.

Among the special papers forming Part II, those of Mr. T. Nelson Dale, on the Rensselaer grit plateau in New York, and of Prof. I. C. Russell, on his second expedition to Mt. St. Elias, have been already reviewed in the last volume of the AM. GEOLOGIST (pages 54 and 190, July and Sept., 1894); and the four other papers are noticed in the following pages of this volume.

Part III, on the surveys for plans of irrigation in the arid region comprising the greater part of the western half of the national domain, consists of the report on Water Supply, by Mr. F. H. NEWELL, noting the rainfall and gauge measurements of streams, with maps of irrigated and irrigable lands, and of pasture and timber lands, in the Missouri, Yellowstone, and Platte river basins; two reports by HERBERT M. WILSON, one being on American Irrigation Engineering, considering its economic and financial aspects, different kinds of canals, weirs, dams, and reservoirs, and the other on Engineering Results of the Irrigation Survey, as developed in the basin of the Arkansas river, Colorado, of the Sun river, Montana, of the Truckee and Carson rivers, Nevada, in the High Sierra reservoirs, California, the El Paso reservoir on the Rio Grande, Texas, and the Pocatello canal in Idaho; and two reports by A. H. THOMPSON upon the construction of topographical maps and the selection and survey of reservoir sites in the hydrographic basin of the Arkansas river, Colorado, and upon the location and survey of reservoir sites in Utah and Idaho during the fiscal year ending June 30, 1892. A most important element in the plans of irrigation for many districts is found to be the fluctuations in the rainfall, with occasional deficiency or entire failure of streams during seasons of exceptional drought.

W. U.

Sulla Serpentina d' Oira (*Lago d' Orta*) *e sopra alcune roccii ad essa associate.* FRANCESCO SANSI. (Rendiconti Reale Inst. Lombardo di Sci. e Lit., (2), vol. XXV, pp. 681-688. Milano, 1892.) In this paper are described the rocks of a small but very interesting petrographical province lying in the north of Italy. The rocks include stratified amphibolites, serpentine, amphibole gneiss, altered granite and quartzite. More specifically they are:

(1) Altered granite of the Val Pellino. This is a dusky white rock flecked with greenish spots. Its principal constituent is quartz variously orientated. The feldspars present include both orthoclase and plagioclase. Biotite, altering to chlorite, and pyrite are present, as are also zircon and apatite as inclusions. The orthoclase occurs as large turbid individuals, having crystalline form in part, and being in part altered to kaolin. The plagioclase shows a zonal structure, with alteration setting in from the periphery. Among the alteration products are calcite and epidote.

(2) Bodies of quartzite compressed in the granite. These are compact masses of scaly fracture and dusky gray to translucent glassy

color. They are holocrystalline with bipyramidal quartz, microcline, muscovite, chlorite, pyrite, and zircon having pleochroic aureoles.

(3) Gneiss without amphibole of the Val Pellino. This is distinctly stratified, has a granular structure, and is composed of quartz predominantly, orthoclase and plagioclase, biotite with inclusions of magnetite, and associated chlorite and muscovite, apparently alteration products. Zircon occurs as an inclusion in quartz, with a mineral doubtfully recognized as cordierite. Andalusite is also present.

(4) Amphibole gneiss stratified with amphibolite. This rock shows slightly different phases, but is always schistose. It is made up of quartz, orthoclase, plagioclase, and amphibole. The latter is of intense green color and characteristic pleochroism.

(5) Amphibolite. This has a uniform dark green color and is made up of a network of acicular crystals of amphibole traversed by rare veins of quartz or feldspar, the latter mainly plagioclase.

(6) Serpentine. This is represented by a considerable mass of dark green mineral, traversed by small and more or less sinuous veins. Under the microscope, the mass is seen to be individualized, the green mineral breaking up into small intricate bands. Dispersed granules of high relief and without crystalline form are noticed. These granules are surrounded by serpentine. A mineral giving high interference colors and with fresh aspect is referred to actinolite. Muscovite and chlorite as alteration products, and granules of magnetite, are noticed. An undetermined mineral, undoubtedly represented in the granules of high relief, is present. Since, however, the crystalline form, and for the most part even the cleavage lines, are lacking, diagnostic characters are not present. This mineral has been considered to be olivine because of the high colors of polarization; but the author considers this reference incorrect. Where the granules are separated by serpentine, a web structure is seen, the strings being serpentine, and the intervening spaces being filled with the mineral in question. These lines meet at an angle of about 90.° Such a structure has been described by Hussack as "balkenstructur," and is characteristic of pyroxenite serpentine. The mineral here shows kinship to both orthorhombic pyroxene (enstatite?) and to monoclinic (salite?).

The observations exclude the belief that the serpentine is derived directly from the amphibole, and confirm rather the opinion of Cossa that it comes from pyroxene. H. F. B.

The geologic history of Rochester, N. Y. By H. L. FAIRCHILD. (Proc. Rochester Acad. Sci., vol. II, pp. 215-223, June, 1894.) In this paper Prof Fairchild has given a sketch of that part of geologic history which can be read from the rocks at Rochester. The strata below the upper part of the Medina are known only from drill records which go down over 3,000 feet. The lowest rocks mentioned are a siliceous limestone and a ferruginous quartz rock, whose exact age is uncertain; they immediately underly the Calciferous. A large part of the section is composed of 834 feet of Trenton dark limestone and 1,075 feet of Medina red

sandstone and shale. The strata from the top of the Medina up to and including the Niagara limestone, can be studied in the Genesee ravine. From the Niagara to the present no deposits, except those of glacial origin, are known. U. S. G.

The length of geologic time. By H. L. FAIRCHILD. (Proc. Rochester Acad. Sci., vol. II, pp. 263-266, July, 1894.) This article will be of value for reference, as it gives a concise statement of the various estimates, from that of Charles Lyell to the recent ones of King, Upham, Walcott and others, of the time required for the deposition of the sedimentary rocks of the globe. Nineteen different estimates, with complete bibliographic references, are presented. U. S. G.

Preliminary report of field work during 1893 in northeastern Minnesota, chiefly relating to the glacial drift. By WARREN UPHAM. (Geol. and Nat. Hist. Survey of Minnesota, 22d [1893] Ann. Rept., pt. III, pp. 18-66, pls. 1 and 2, 1894.) The first part of this paper is devoted to a brief outline of the topography of the northeastern part of the state, and the altitudes of a large number of points are given; these are taken from railroad profiles and from recent determinations made by members of the Minnesota Survey. Following this are descriptions of the only rock outcrops known in Aitkin and Cass counties.

The most important and interesting part of this report is that treating of the glacial drift; an outline of the glacial geology is given and special attention is called to certain points, the chief of which are mentioned below. A map is presented, which, among other features, shows the results of the most recent work as to the location of the moraines in the northern part of the state, and the area occupied by Beltrami island of the glacial lake Agassiz; this island lies just to the northwest of Red lake. A very complete list of glacial striæ is given, and attention is called to the divergent directions of these striæ at certain points, the most marked being in the vicinity of Duluth. Drift from three principal sources is recognized: (1) on the west, from the north and northwest; (2) east of the Big fork, from the north and northeast; and (3) in the same region, from the east. Drift from the last direction is easily recognized by its boulders, which are characteristic of the rock of the Keweenawan areas on the north shore of lake Superior. Several sections from cuts on the Mesabi range show alternations of layers of till from the last two directions. The locations of four moraines north of lake Superior are indicated much more accurately than has heretofore been possible, and the most northerly, named the Vermilion or Twelfth moraine, is here described for the first time.

Several pages are devoted to a discussion of the raised beaches on the north shore of lake Superior, and a brief account is given of the history of the ice-dammed lakes that made these beaches. Three beaches are referred to the Western Superior glacial lake, eight to the glacial lake Warren, and one to the glacial lake Algonquin. The last beach is united with the present beach at Duluth, but it gradually ascends eastward, reaching a hight of 49 feet above lake Superior at Sault Ste.

Marie. Nine distinct deltas are mentioned at Duluth as having been made by Chester creek at different stages of these lakes. U. S. G.

The lherzolite-serpentine and associated rocks of the Potrero, San Francisco. By CHARLES PALACHE. (Bull. Dept. of Geol., Univ. of California, vol. I, no. 5, pp. 161-180, Aug., 1894.) A rather detailed account of this serpentine is given in order to disprove the supposition that there are no serpentines of igneous origin in the Coast ranges. It is shown that the rock was originally a lherzolite, i. e., was composed chiefly of an aggregate of enstatite, diallage and olivine, unaltered portions of which minerals are still to be seen. Cutting this lherzolite-serpentine are masses of hypersthene diabase and epidiorite, the hornblende of the latter being probably secondary after pyroxene. U. S. G.

On a rock from the vicinity of Berkeley containing a new soda amphibole. By CHARLES PALACHE. (Bull. Dept. of Geol., Univ. of California, vol. I, no. 6, pp. 181-192, pls. 10-11, Aug., 1894.) The material studied comes from a large boulder, which is probably near its parent ledge, about three miles north of Berkeley. The rock has a white matrix of saccharoidal albite, in which matrix are prisms of a blue amphibole. An investigation shows that this mineral is intermediate in chemical composition between glaucophane and riebeckite, that it is similar to the latter mineral in the relation of the axes of optical elasticity to the crystallographic axes, but that the extinction angle is about twice that of riebeckite; the pleochroism is also a little different from that of riebeckite. Since an almost exactly similar amphibole, as far as optical properties are concerned, has been reported from Colorado by Dr. Whitman Cross (Amer. Jour. Sci., III, XXXIX, 359-370, 1890), the author proposes the name *crossite* for the mineral here described. The Coast ranges of California have long been known to contain schists with a blue amphibole, which has been referred to glaucophane, but which it is believed will be found to be largely crossite. U. S. G.

The Great Ice Age and its relation to the Antiquity of Man. By JAMES GEIKIE. Third edition, largely rewritten. Pages xxviii, 850, with 18 maps and charts, a frontispiece, and 78 woodcuts, including numerous full page illustrations, in the text. (London: Edward Stanford, 26 & 27 Cockspur street, Charing Cross, S. W., 1894.) First published in 1874, about a year before the closely related treatise by Dr. James Croll, *Climate and Time*, this work was largely extended in its second edition (1877), and the same author four years later presented a continuation of his studies of the Glacial and Postglacial periods, in his almost equally notable volume, *Prehistoric Europe*. During the thirteen years which have passed since then, he has been industriously adding to his data for the present new edition, which has 225 pages more than the second. Its most regrettable omission is the appendix, appearing in the first and second editions but not in this, entitled "List of the fossil organic remains of the glacial deposits of Scotland," by Robert Etheridge, Jr., with bibliographic references and concise descriptive notes of most of

the localities yielding these fossils. As here newly edited and for the greater part rewritten, with two chapters by Prof. T. C. CHAMBERLIN, on the "Glacial Phenomena of North America," this volume well sustains its author's eminence as the foremost of living glacialists. It seems not too much to say that this work, in its successive editions, and Dr. Croll's volume before mentioned, have done more than any other contributions among the very extensive mass of glacial literature, since the early grand work of Agassiz, to stimulate many eager students in fruitful investigations of the evidence and history of glaciation and in classification of the glacial and glacio-fluvial formations of Europe, North America and other regions. Like the writings of the author's brother, Sir Archibald Geikie, this account of the Ice age is presented in a very clear and attractive style, commendably adapted to the understanding of ordinary unscientific readers, while yet carefully stating the latest discoveries and theories in this increasingly debated division of geology.

Twenty of the forty-three chapters relate to Scotland, describing its glacial, glacio-fluvial, interglacial and postglacial deposits, striation, rock-basins, ice-sheets, and local glaciers; four chapters relate to England; one to Ireland; three to northern Europe; one to the Urals and the mountains of central Germany; two to the Alps; one to other parts of Europe, as France, Spain, Corsica, the Apennines, Iceland, the Færöe islands, the Azores, and Gibraltar; a chapter of nine pages reviews the glacial succession in Europe; two chapters describe cave-deposits, "valley-drifts," and loess; a chapter of eleven pages summarizes the climatic changes of Europe during the Glacial period, and the evidence of contemporaneous Palæolithic man; the fortieth chapter discusses the glacial phenomena of Asia, Australia, etc., and South America; the next two, by Prof. Chamberlin, relate to North America; and the final chapter treats of the cause of the climatic and geographic changes of the Glacial period.

Six epochs of glaciation, with five interglacial epochs, are recognized, being nearly the same as in the author's paper published in the Transactions of the Royal Society of Edinburgh (vol. XXXVII, pp. 127-149, with map) in 1892, excepting that one more glacial epoch, the latest, with the corresponding interglacial epoch, is here added.

1. The first glacial epoch is represented by the Weybourn crag and Chillesford clay, followed by the interglacial forest bed of Cromer.

2. For the second and maximum epoch of glaciation, an ice-sheet is mapped as stretching from Scandinavia east across the northern two-thirds of Russia to the Urals, the river Obi in Siberia, and Novaia Zemlia; southward to latitude 50° in Russia, Poland, and eastern Germany; and southwest to central Belgium, to the Thames, beyond the southern and western coasts of Ireland, and across the Hebrides and Shetland islands. At the same time the Faröes and Iceland were entirely ice-enveloped. With the Irish, North, Baltic and White seas, the area of this ice-sheet exceeded 2,000,000 square miles. Its limits have been greatly extended eastward since the similar map was prepared for

Prehistoric Europe. This also was the time of greatest extension of the glaciers in the Alps, Pyrenees, and Caucasus. The ensuing interglacial beds of northern Germany contain remains of a temperate flora and fauna, indicating even milder conditions than those of the present day, and the rivers eroded deep valleys.

3. For the third glacial epoch, ice-sheets covering Ireland, Scotland, northern England, and Wales, are represented as confluent with the Scandinavian ice-sheet, which reached south to Hamburg, Berlin and Warsaw, and east to the Valdai hills and White sea. During the next epoch of interglacial conditions, the Baltic sea is shown to have had a temperate marine fauna, while the adjacent lands of northern Germany had a corresponding terrestrial fauna and flora.

4. In the fourth glacial epoch, or that of the Great Baltic glacier, delimited by conspicuous moraines, the ice-sheet covered nearly all of Scandinavia, excepting a considerable tract of southern Sweden: it reached east over a large part of Finland, and south along the Baltic trough to the lowlands of northern Germany and eastern Denmark: but the North sea existed as now, and the British Isles had only local or district ice-sheets of comparatively small extent. The next interglacial epoch had forests of deciduous trees farther north than they now flourish; and the Baltic was for a time converted into a fresh-water lake, named the Ancylus lake from its most characteristic fossil shells, as made known by the studies of Baron de Geer and others, but later it was connected with the sea by straits across southern Sweden, admitting a marine molluscan fauna of somewhat more temperate character than now. While the Baltic was a lake, the bed of the North sea, the English channel, and large tracts which are now shallow sea surrounding the British Isles, and a belt thence to the Færöes and Iceland, are mapped as land, whereby the European flora was extended to Iceland and Greenland. That migration may, however, as the reviewer thinks, be better explained otherwise, as stated farther on.

5. The fifth glacial epoch is represented only by local or valley moraines in the British Isles, the snow-line in Scotland having been at an average hight of 2,500 feet.

6. After an interval of forest growth in the mountain valleys, another and the final epoch of local glaciers, occurring only on the highest mountains in Scotland, had its snow-line at the hight of 3,500 feet.

Prof. R. D. Salisbury, reviewing this volume in the Journal of Geology (vol. II, pp. 730-747, Oct-Nov., 1894), well notes the remarkable parallelism of the European and North American glacial history, "that the outermost border of the drift in Europe, as in America, is not characterized by terminal moraines: that the limit of the drift deposited during the second advance of the ice [Prof. Geikie's third glacial epoch] in Europe, as in America, is not commonly marked by well-defined moraines, though moraines are not altogether wanting: that the great body of loess in Europe, as in America, seems to be connected with the ice advance which succeeded the greatest: and that the ice during the next succeeding advance (the second after the greatest), both in Europe and

America, developed the great terminal moraines, and that these moraines are bordered on the outside by plains and valley trains of sand and gravel, denoting more vigorous drainage than during the earlier stages of the ice." Commenting on this, the present reviewer would inquire, May not the close agreement in the glacial succession on the two continents be more probably in each case the expression of varying physical conditions of the increase, culmination, and especially the decline, of a single cycle of glaciation, rather than the records of several independent epochs of ice accumulation and departure?

Applying the interpretation of these series of glacial and interglacial deposits which seems to find warrant in Russell's observations of the Malaspina ice-sheet in Alaska, covered on its border for a width of several miles with drift on which forests, thickets, and abundant herbaceous flowering plants of temperate species grow luxuriantly, we may attribute all the complex sequence of drift formations in Europe, as in North America, according to the opinion of the reviewer, to moderate fluctuations of the boundaries of the ice-sheet and of its waning remnants, during a continuous Glacial period of probably no longer duration than 20,000 or 30,000 years. While the ice-sheets were being accumulated, doubtless a severely boreal and arctic climate prevailed in these regions; but when the formerly greatly elevated lands had sunk under their ice burden to their present altitude or lower, a warm temperate climate was restored, similar to that which now characterizes the low latitudes from which the ice was being melted away. Any reädvance of the ice-border would then cover remains of a fauna and flora consisting wholly or chiefly of temperate species. Under this view, the time divisions which Prof. Geikie calls epochs seem more properly to be considered as episodes or stages in a single epoch or period of continuous though fluctuating glaciation.

Professor Chamberlin's two chapters contain, in 52 pages with two maps, a very comprehensive and valuable statement of the chief features of North American glacial geology. In all the grand outlines and most of the conclusions, as the explanation of practically all our drift phenomena by land-ice, the reviewer is in hearty accord, so that it is almost trivial to refer principally, as in this notice, to the following points where he would differ in the inferences from recorded observations. The Laurentide and Cordilleran ice-sheets should probably be shown as confluent across the low portion of the Rocky mountains in the region of the Peace river and northward, during the maximum stage of glaciation; the greatest thickness of the Laurentide ice-sheet may have extended along an east to west belt somewhat south of the Labradorean and Hudsonian centers of outer radiating striation and drift transportation; the northward glacial flow from southern New England toward the St. Lawrence, as suggested by Chalmers, appears to have belonged only to a very late stage when the melting of the ice in the St. Lawrence valley, proceeding faster than on the [illegible] area at the south, left there a large isolated remnant of the departing [illegible]; the imbrication or overlapping of [illegible]

trated in the frontispiece and text descriptions, may be due, in some places where it is most complex, to changes in the directions of currents in one and the same ice-sheet on the same area at different times, such as are found to have prevailed in eastern and northeastern Minnesota, being there comprised wholly within Prof. Chamberlin's latest or East-Wisconsin division of the declining part of the Ice age; and the interglacial fossiliferous beds of Toronto and Scarboro, Ont., seem referable to a stage in the glacial retreat when lake Iroquois, the glacial representative of lake Ontario, had begun to outflow by Rome, N. Y., to the Mohawk and Hudson rivers, after which the epeirogenic uplifting of the Rome outlet caused the lake level at Toronto to rise to the high Iroquois beach, the glacial reädvance that covered the fossiliferous delta beds having been probably only a moderate fluctuation of the ice-front, till this time lingering on the highland between Toronto and Georgian bay.

Nearly half of North America, or an area of 4,000,000 square miles, was ice-covered. It will be very interesting to learn, from Prof. Chamberlin's observations in northwestern Greenland and from future explorations of the Arctic archipelago, whether this continental ice-sheet was confluent over Grinnell land and Smith sound with the Greenland ice. The terminal or retreatal moraines of the Laurentide portion of the North American ice-sheet, traced across the northern United States to the northwestern plains of Manitoba and Assiniboia by Chamberlin, Smock, Lewis and Wright, Todd, Leverett, Salisbury, Upham, and others, afford most impressive proof of the land-ice origin of our drift; and these twelve to twenty or more moraines, marking pauses in the glacial recession, are accepted as all belonging to the closing part of the whole history of the Ice age.

The distinction of the successive portions of the North American glacial drift in the order of their age by geographic names, as the *Kansan*, *East-Iowan*, and *East-Wisconsin* formations, here proposed by Prof. Chamberlin, seems to be clearly a step of progress. It would perhaps be better, however, for reasons of euphony, to shorten the two latter names simply to *Iowan* and *Wisconsin*, which, with their definitions, will be sufficiently understood. This system of nomenclature is elastic, permitting interpolation and elimination, and it leaves the question open for further investigation and discussion, whether the Glacial period was dual, threefold or more complex, with one, two or more interglacial epochs, or, on the other hand, was essentially continuous, with comparatively small oscillations of the ice boundaries during both the growth and decline of the ice-sheet.

Concerning the causes of glaciation, Profs. Geikie and Chamberlin doubt the adequacy of Dr. Croll's astronomic theory, which a few years ago obtained more general assent; but they fail thus far to approve the alternative epeirogenic theory of Dana, Le Conte, Wright, Upham, Jamieson, Falsan and others, which attributes the ice accumulation to great uplifts of the land bringing a snowy climate throughout the year. This view, however, will explain how the Færöe islands, Iceland and Greenland, may have received their largely European floras; for if the

high elevation which Prof. Geikie places after his fourth glacial epoch were instead during preglacial time, bringing on the ice-sheets, low shore tracts of the land bridge to Greenland may never have been covered by the ice and so would preserve the flora for Iceland and Greenland when this part of the earth's crust subsided and the Ice age ended.

The duration since the departure of the ice from the temperate portions of Europe and America is thought to have been less than Dr. Croll's theory would require. For our continent Prof. Geikie presents Dr. J. W. Spencer's discussion of the age of Niagara falls, regarding this time as about 32,000 years. Evidence now in hand, however, seems to prove that no outflow passed from lakes Superior, Michigan and Huron to the Mattawa and Ottawa, on which the greater part of Dr. Spencer's estimate is founded. Probably 7,000 years is as close an approximation to the duration of Niagara and the Postglacial period as we can attain.

Twenty years ago the present writer derived his earliest interest in our glacial and modified drift from a perusal of the first edition of *The Great Ice Age*. This third edition will be read by all glacialists with much renewal and increase of enthusiasm for the many Pleistocene questions which still remain debatable. Every page is richly suggestive, and the theory of alternating glacial and interglacial epochs has served well for the collection and orderly arrangement of a vast mass of information as to the Ice age and its complicated history. W. U.

The Ore Deposits of the United States. By JAMES F. KEMP. (8vo. pp. i-xvii, 1-343, with 94 illustrations: revised and enlarged: Scientific Publishing Co., New York and London, 1895.) This work has already been reviewed in THE AMERICAN GEOLOGIST (vol. xii, pp. 268-269, Oct., 1893), and it is only necessary here to call attention to the revised and enlarged edition. "In the second edition many pages have been rewritten and expanded. The endeavor has been to introduce into the body of the work the new materials that have become available in the last year This is especially true of iron ores, of the geology of the Sierras and of nickel and cobalt. In all some fifty pages of new matter have been added, and fifteen cuts." The publication of a second edition of this book within less than two years after the first edition was issued is sufficient evidence of its usefulness and value. U. S. G.

The geology of Angel island. By F. L. RANSOME. *With a note on the radiolarian chert from Angel island and from Buri-buri ridge, San Mateo county, California.* By J. G. HINDE. (Bull. Dept. of Geol. Univ. of California, vol. 1, No. 7, pp. 193-240, pls. 12-14, Oct., 1894.) Angel island is three and a half miles north of San Francisco and is composed largely of San Francisco sandstone and a jaspery rock (radiolarian chert). The chief geological interest centers in the phenomena connected with the igneous rocks of the island, which are chiefly a large dike of serpentine and an intrusive sill. The rock of the sill varies considerably, but its characters seem to ally it more closely with the fourchites described by J. F. Williams from Arkansas than with any other class of rocks. In

the serpentine the only original mineral now distinguishable is diallage. A narrow belt of glaucophane schist frequently occurs at the contact of the country rock with both the serpentine and fourchite. As this schist is clearly a product of contact action, all of the glaucophane schists of the Coast ranges can not be referred to regional metamorphism, as has heretofore been done. The glaucophane is developed in the cherts as well as in the sandstones.

The chert (phthanite of Becker) is found to contain abundant remains of radiolarians, so poorly preserved, however, that specific determination is out of the question. Several figures of these fossils are given, and Dr. Hinde is able to refer some of them to certain genera: he calls attention to the number and variety of the forms of the genus *Dictyomitra* which are present. C. S. G.

Geological Survey of Missouri, Sheets Nos. 2 and 3, the Bevier sheet and the Iron Mountain sheet. ARTHUR WINSLOW, state geologist. Jefferson City. Published by the Geological Survey.

Each of these "sheets" is accompanied, the former by three, and the latter by two, other sheets of the same size as the sheets themselves, and they are included separately in two paper covers or folios. Each sheet has a description sheet, giving briefly an account of the geology of the area of the sheet, while on the other accompanying sheets are perpendicular and cross-sections illustrating the geological structure. Each sheet covers an area fifteen minutes of latitude by fifteen minutes of longitude, making approximately a rectangular parallelogram of convenient proportions. The scale is $\frac{1}{62500}$ of nature, or approximately one inch to the mile. Based upon latitude and longitude they do not agree with the boundaries of towns and counties, although the town and county lines are expressed on them, as well as the section lines of the land survey. They are both marked in detail by contour lines, the interval being 20 feet. The Bevier sheet was done under the charge of C. H. Gordon, with C. F. Marbut and M. C. Shelton as assistants. The Iron Mountain sheet is by the state geologist, who had the aid of Erasmus Haworth on the crystalline rocks, and E. H. Lonsdale and C. F. Marbut as topographers and geological assistants. The Bevier sheet was engraved in Washington, D. C., by Evans and Bartle, and is dated October, 1893. The Iron Mountain sheet was engraved by George S. Harris and Son, at Philadelphia, and is dated January, 1894. One other similar sheet has been issued—the Higginsville sheet, noticed in the GEOLOGIST, vol. x, p. 317. No other state survey has attempted so detailed topographical work nor so costly and elaborate a system of mapping. These sheets compare, to their advantage, with those of the United States Geological Survey; and if the State of Missouri persists in this enterprise to the completion of the survey, on this scale of excellence, she will not only be far in advance of her neighbors, but will rank with the States of central Europe. N. H. W.

Geological Map of Alabama, with an explanatory chart. EUGENE A. SMITH, state geologist. Montgomery, 1894.

Greatly in contrast with the foregoing is this excellent map of Alabama and its synoptical companion sheet. It covers the whole state but has no topographical contours. It is published with the well-known excellence of engraving of Julius Bien and Company, of New York. Its size is about twice that of one of the Missouri sheets, and its publication with its companion sheet probably cost about the same sum as one of the Missouri sheets. The great contrast to which we refer is not in the degree of excellence of the geological work, for they both illustrate the best of geological work. It is rather in the plan, the history and the utilitarian results achieved by the two surveys, for after all, the practical good that comes to society from such enterprises is the final arbiter which determines their existence or decrees their death. The highest flights of technical science, whether in physics or in geology, are amenable to this arbiter, and probably more certainly so in the democratic communities of the United States than elsewhere in civilized countries. Dr. Smith seems to have realized this, and has moved slowly toward his contemplated result, making as much haste as was safe; every step has had its utilitarian aspect foremost, while the additions that he has made to science have not been few. His survey is probably more firmly grounded in the good will and appreciation of the intelligent citizens af Alabama than ever before. This map of Alabama is the best ever published of that state, and [illegible] uses for which such a map is wanted for ma[illegible] The Alabama survey has not been wrecked on [illegible] of pa[illegible]ontology or topography. While a[illegible] and outlined them both for [illegible] The Missouri survey struck the topograph[illegible] spent much time and money [illegible] not wrecked, but is damaged [illegible] reaches safe sailing again, it [illegible] geological science in the esteem of [illegible]

The Geological History of Harbors. [illegible] An. Rep., U. S. Geol. Survey, Part II. [illegible] and figures 7-15 in the text.) This pap[illegible] bors on the settlement and development [illegible] ologic conditions by which the harbors [illegible] tem of classification; geologic processes [illegible] them, with suggestions as to the means wh[illegible] favored or hindered through the agency of [illegible] tures of the ports on our Atlantic and Pacific [illegible] great Laurentian lakes, which are now or ma[illegible] our foreign or domestic commerce. In the [illegible] their several genetic kinds are named delta, [illegible] fjord, mountain range, glacial moraine, lagoon [illegible] volcanic crater, and coral reef harbors. The wor[illegible] of our harbors by the U. S. Engineer Corps, and [illegible]

drographic surveys of all our coast lines, and especially in the vicinity of the principal harbors, by the U. S. Coast Survey, have been freely used by the author, making a very instructive and valuable memoir of exceptional popular interest. Concerning oscillations of the land, which contribute very largely to the formation and changes of harbors, Prof. Shaler says: "Although there is much evidence to show a process of depression along the Atlantic coast line, recently operative, and probably still in progress at certain points, and the known facts of the Pacific coast point to similar movements there, and although there is, furthermore, evidence tending to show a very modern uprising along the coast from New York northward, the shores of our continent may fairly be considered as in a tolerably stable condition." W. U.

The Mechanics of Appalachian Structure. By BAILEY WILLIS. (Thirteenth An. Rep., U. S. Geol. Survey, Part II, pp. 211-281, with plates XLVI-XCVI, and figures 16 and 17.) The most common types of mountain ranges, and the causes and conditions of their formation, are nowhere better displayed than in the Appalachian mountain belt, stretching 900 miles from New York to Alabama, with a width from 50 to 125 miles. Great thicknesses of Paleozoic sediments, which were there deposited on the western border of a continental area, are compressed into long and narrow parallel folds, sometimes overturned and overthrust. From the early work of H. D. and W. B. Rogers to the recent studies of the long overthrust faults by Hayes and Campbell, this belt has held a prominent place in the growing literature on the structure and origin of mountain ranges, to which the present work is probably the most important contribution yet made by American authors. Four districts in the Appalachian province are each distinguished by a prevailing structural type, namely, the district of open folding in the Alleghany region of Pennsylvania and West Virginia; the district of close folding along the Appalachian valley; the district of folding and faulting in the Southern Appalachian region of Virginia, Tennessee, and Georgia; and the district of folding with schistosity in the Smoky mountain region.

Attempting in the laboratory an experimental reproduction of folds and faults in alternating hard and soft strata, as had before been done by Sir James Hall, Favre, Schardt, and Cadell, the author used beeswax to represent the rock formations, mixed in varying proportions with plaster of Paris to harden it, and with Venice turpentine to soften it, so obtaining a range in quality from brittle solid to semi-fluid. Plasticity in the earth's crust being a result of pressure due to load, this condition was imitated by placing a body of shot, heavy, but yielding and convenient to handle, above the strata. A maximum weight of 1,000 pounds was used, evenly distributed over the models, giving a pressure of five pounds per square inch. The machine for imitating the lateral pressure by which the mountain strata were folded and upheaved was a strong oak box with a piston which could be advanced by a screw.

The models and experiments were designed in accordance with the accepted conception of the earth's crust as "a superficial shell 5 to 7 miles thick, which rests upon and grades in substance and physical condition into a subjacent shell. The under is only differentiated from the upper by its relative position in consequence of which it supports a crushing load and forms a latently plastic foundation." More tersely stated, the geologic condition to be imitated was that "the strata which have suffered folding and faulting floated upon and graded downward into a latently plastic mass." It was further required that the thickness and extent of the strata should be so related that as a whole they should be flexible rather than rigid. The principles which had been stated by Heim, Gilbert and others, that deformation by fracture, with shearing and overthrust, occurs under moderate load, and that deformation by flexure, with open or closed and finally overturned folds, takes place under great load, are well proved by these experiments. In the very extensive and admirable series of illustrative plates we are shown the gradual development of every stage and phase in the formation of mountain folds and faults.

Mr. Willis concludes that the vast lateral pressure producing the Appalachian and other mountain belts can not have been due wholly to the contraction and shrinking of the earth's interior. He would therefore add to that partial explanation the theories of Dutton and Reade. The resulting composite theory is advocated as follows: "To every hypothesis brought forward to account for the folding of the stratified rocks there is one objection made by its opponents: The cause is not quantitatively equal to the task required of it. For argument's sake, admitting for each and every one that the criticism is sound, I do not understand that it disposes of any which are based on good inferences from observed facts. The process of deformation was exceedingly complex and thus afforded opportunity for the action of more than one cause. As the work performed was stupendous, it required the combined power of all available forces."

Referring to the yet more difficult question of the causes of the partially concomitant but (according to the opinion of Mr. Willis) unrelated epeirogenic uplifts and growth of this continent, he writes: "The Paleozoic continent and sea of North America had their origin in unknown causes of pre-Cambrian time. After Paleozoic deposition and deformation the rise of the whole continent lifted alike the Blue Ridge belt of crystallines, the folded zone of the Appalachian province, and the undisturbed strata of the Mississippi basin. The uplift bore no relation in area or time to the fact of compression, and it has gone on through geologic periods after folding ceased, as is shown by the ancient base levels and revived drainage of the whole region east of the Mississippi valley." To the reviewer it seems more likely that an intimate genetic relationship existed between the Appalachian revolution of mountain folding and the accompanying rise of the interior of North America from the previously very long enduring Paleozoic sea; and the

later epeirogenic movements of this region may well have been similarly related, in common causation, with orogenic folding and faulting of our Cordilleran mountain belt. W. U.

The Average Elevation of the United States. By HENRY GANNETT. (Thirteenth An. Rep., U. S. Geol. Survey, Part II, pp. 283-289, with plate CVII.) From the compilations of altitudes which are published in Bulletins 5, 72 and 76 of this survey, and from all other available hypsometric data, a contoured map of the United States on a scale of $\frac{1}{2500000}$, or about 40 miles to an inch, has been published, from which the map forming plate CVII, folded in the pocket of the volume, has been produced by reduction. This map is on the scale of about 105 miles to an inch, and is colored to display the areas between the successive contour lines of the seashore and 100 feet, 500 feet, 1,000, 2,000, 5,000, 8,000 and 11,000 feet above the sea. In his paper Mr. Gannett states the mean altitude of each state and its respective areas between these and other intercalated contour lines. The mean altitude of the whole United States is found to be approximately 2,500 feet. Delaware, with a mean hight of about 60 feet, and Florida, about 100 feet, are the lowest states, while Wyoming, at 6,700 feet, and Colorado, at 6,800 feet, are the highest. Since the publication of this paper, a careful determination of the mean altitude of Minnesota, from the contoured maps prepared by the geological survey of that state, has given it as approximately 1,224 feet, quite well agreeing with Mr. Gannett's estimate, which is 1,200 feet. W. U.

CORRESPONDENCE.

REMARKS ON THE BERNER OBERLAND SECTIONS OF PROF. H. GOLLIEZ IN THE GEOLOGICAL HANDBOOK OF SWITZERLAND, 1894.*

Mr. Golliez has published in the "Livret Guide" two sections of the Bernese Oberland which vary so materially from all previous results that I feel myself compelled to a reply, all the more because this book is certain of a wide distribution and I see that the new theory has created surprise among Swiss geologists.

1. Section Meiringen-Innertkirchen by Mr. Golliez p. 207.

Mr. Golliez assumes it is true a great flat fold, but puts instead of Malm, Trias! in contradiction to all previous observers.

The trough nucleus of Lias and Dogger rises according to him theoretically towards the middle of the Pfaffenkopf wedge, Dogger and Lias are assumed as doubled in the Unterwasser section: at the entrance to the gorge of the Aar at Meiringen they bend back upwards.

There must be weighty reasons which induce Mr. Golliez to place himself in contradiction to all the geologists who have hitherto studied this region.

*Translated by Dr. Persifor Frazer from a circular distributed at Zurich at the late meeting of the International Congress of Geologists.

One reads with astonishment of "poor fossils absolutely incompetent to inform us with certainty" (by this the Triassic Diploplora are meant), whereas I refer to the extended Belemnites, which I know in the eastern continuation of the chain, for the view held till now. Mr. G. depends more on petrographic "habitus" and an insecure analogy with the "Briançonnais;" he thinks there are occurrences of "intercalations" of quartz, sandy Dolomite, and Gypsum. Up to this time only Limestone and secondary segregations have been seen as they occur in every limestone: possibly Mr. G. has allowed himself to be deceived by Röthidolomite folded from below upwards. (Compare my section Sheet ix, fig. 1, right hand side.) But how any one can make Triassic dolomite on such a basis out of our high mountain limestone is undiscoverable.

In the Unterwasser section (compare my figure 4) I know of no repetition of the beds.

In the nucleus of the Pfaffenkopf wedge there is no Lias; on the other hand it occurs on the boundary towards the Gneiss at Ahorni, where according to G.'s hypothesis it ought not to occur, and where besides the wedge is wrongly drawn.

Mr. G. opposes or finds fault with the presence of Eocene on sheet xiii in Reichenbachthal, etc. Inexplicably the important Eocene trough of this valley corroborated by myself and Mösch, which has been absolutely established by Nummulites, largely developed Taveyannaz sandstone, and Flysch, seems to have escaped him.

The statement on p. 209 that I assume Flysch on my older chart along the foot of Bernese Oberland mountain wall, where Dogger exists, is incorrect as my legend proves. Provisionally Dogger, Oxfordian, and Eocene were indicated there in the same color, because their boundaries were not at that time settled. This "pretended Flysch" exists only in the fancy of Mr. Golliez.

In fine, the section by Mr. Golliez of Meiringen to Innertkirchen so far as it is correct has long been known, and where it would offer surprising novelties it is wrong.

2. **Transverse section of the Bernese Oberland, by H. Golliez: page 212.**

Under this pompous title a section from the Mönch to the Habkehren valley is given, in regard to the northern part of which Mr. Golliez will have to explain himself to Mösch: only the southern half concerns me.

The discovery which Mr. Golliez made in the gorge of the Aar recurs here again, but he is more sure of his affair; the flanks (Abstürze) of the Mönch are said to be Triassic-marble according to the section. Whoever, at the little Scheidegg, sees only occurrences of marble may imagine that the Mönch is marble up to its gneiss cap. In fact, the marble is a very small factor compared to the ordinary high mountain limestone. Dolomite has nowhere been observed, and as little has the Opalinien bounded by marble.

Mr. Golliez's Trias hypothesis (or better, illusion) is wrong for the Mönch also, and has not a trace of holding ground. Were it correct, for consistency's sake, on many of the Dufour sheets Malm would have to

be transformed into Trias, even where it is paleontologically well supported by the presence of Tenuilobatus beds and Tithon. To designate the non-fossiliferous part as Trias is indefensible from petrographic and tektonic considerations.

Mr. G.'s section is wrong. The Malm nucleus sinking into the valley near Lauterbrunnen is to be united with the Oxfordian between Männlichen and Tschuggen above: and further away, with the Malm of the slopes of Lütschenthal.

The relations are here relatively simple and by their help the otherwise unintelligible Wetterhorn section, p. 208, is easier to comprehend with the quite abnormally placed Eocene. This section is besides wrongly printed, since on the right hand of the Wetterhorn summit fossiliferous Upper Dogger should have been placed instead of marble. It is true this occurrence is not consistent with Mr. Golliez's Trias hypothesis.

The cut of the "Glissement" on the gneiss, of which further explanations are wanting, is original.

In a word, Mr. Golliez's sections are very well adapted to create confusion in the minds of those who are not acquainted with the facts: they do not belong in a "Livret-guide, whose purpose is not to disseminate undigested hypotheses, and I consider myself under the circumstances justified in opposing these geological improvements of the Oberland.

(Signed) A. BALTZER,
Professor in Bern.

INEQUALITIES IN THE OLD PALEOZOIC SEA BOTTOM. You will be interested to learn that gray granite, similar to that found at LeMars, was struck at Sioux City at the depth of 1,515 ft., or 355 feet below the sea level. It was penetrated about 500 feet and showed characters similar to those found in the LeMars well. At the latter point granite was struck at 1,000 ft., about 150 feet above the sea, a difference of 500 feet in a distance of 25 miles. Crystalline schist was brought up by a diamond drill from 560 feet at Pawnee City, Pawnee Co., Neb., as I believe Prof. L. E. Hicks has published. That, I estimate, to be not less than 620 feet above the sea. Yet at Brownsville, 35 miles northeast, a drill was sent down 1,000 feet, probably 100 feet below the sea, without passing through the Carboniferous. At Omaha a boring to the depth of 1,782 feet, 785 below the sea, failed to clearly reach the Silurian. This gives us a glimpse of the irregularity of the old Paleozoic sea bottom, and shows that the Carboniferous is considerably thicker than estimated by Dr. White in his report on Iowa. J. E. TODD.

Tabor, Iowa, May 12, 1890.

PERSONAL AND SCIENTIFIC NEWS.

THE GEOLOGICAL DEPARTMENT AT JOHNS HOPKINS UNIVERSITY. Since the death of Prof. George H. Williams the courses of

instruction in geology at the Johns Hopkins University have been somewhat changed. The department of geology is now under the direction of Dr. Wm. B. Clark, Professor of Organic Geology, assisted by Dr. E. B. Mathews, Instructor in Mineralogy and Petrography. In addition to the instruction given by these two gentlemen, Mr. G. K. Gilbert and Mr. Bailey Willis, both of the United States Geological Survey, will give courses of lectures on physiographic geology and on stratigraphic and structural geology respectively.

BALTIMORE MEETING OF THE GEOLOGICAL SOCIETY.

The seventh annual meeting of the Geological Society of America was held, under the presidency of Prof. T. C. Chamberlin, in the geological laboratory of the Johns Hopkins University, Baltimore, Md., from Thursday to Saturday, December 27th to the 29th. Sixty or more fellows of the society were in attendance, and fifty papers were presented. Pres. D. C. Gilman, speaking in behalf of the university and city, gave a cordial address of welcome. In selecting Baltimore as the place for its winter meeting, the society had counted especially on the presence of Prof. George H. Williams of this university, the second vice-president of the society, as one of those extending to it greetings and hospitality; but his lamented death last summer left to his associate, Prof. William B. Clark, double duty on the local committee and the presentation of an address in memorial of Prof. Williams. A memorial of Mr. Amos Bowman was also given by H. M. Ami.

Three other societies of national extent also held meetings at the same time at the Johns Hopkins University, namely, the American Society of Naturalists, the American Morphological Society, and the American Physiological Society. Many affiliated workers in all departments of the natural sciences, convening from widely different parts of the country, were thus afforded opportunities for most pleasant renewals of old acquaintance; and the several meetings, occupying different rooms of the university at the same time, reminded one of the yet more numerous sections in the annual summer meetings of the American Association. During a part of Friday the Geological Society, on account of its large number of papers, met in two sections, petrographic papers being read in one section, and glacial papers in the other.

Professor Chamberlin, in his address Friday evening as the retiring president, spoke of his observations during the past summer on the glaciers and ice-sheet of Greenland, especially of Inglefield gulf and of Bowdoin bay, a fjord extending from that gulf northward to Lieut. Peary's winter station. A series of very instructive lantern views of these glaciers was exhibited after the address, of which, and of the other glacial and

Pleistocene papers, concise abstracts will be given in the February AMERICAN GEOLOGIST.

After this address about forty fellows of the society had an informal supper, followed by toasts to which Mr. W J McGee, Profs. W. H. Niles and I. C. Russell, and Maj. Jed. Hotchkiss responded. The toast-master, as at the society's former meetings, was Prof. B. K. Emerson, who will be gratefully and laughingly remembered by all present on this and other such occasions, for his felicitous manner of stirring up ripples and waves of merriment where usually there are only calm reflection, profound investigation, and earnest discussion.

The officers elect for the year 1895 are: Prof. N. S. Shaler, president; Prof. Joseph Le Conte, first vice president; Prof. C. H. Hitchcock, second vice president; Prof. H. L. Fairchild, secretary; Prof. I. C. White, treasurer; J. Stanley-Brown, editor; R. W. Ells and C. R. Van Hise, members of the council. Five new fellows were elected. With this addition, the total membership is 234.

It is announced, in the report of the council, that the society's library is to be deposited in the Case Library at Cleveland, Ohio, with facilities for loans to fellows during periods not exceeding two months.

The next meeting of the society will be in connection with that of the American Association, at San Francisco, Cal., in August; but the place of the next winter meeting is not yet determined.

Appended is a list of the papers read at the Baltimore meeting. Many of them were followed with important discussion.

On certain features in the jointing and veining of the Lower Silurian limestones near Cumberland Gap, Tennessee. N. S. SHALER.

The Appalachian type of folding in the White mountain range of Inyo county, California. C. D. WALCOTT.

New structural features in the Appalachians. ARTHUR KEITH.

The faults of Chazy township, Clinton county, New York. H. P. CUSHING. Detailed mapping shows that the nearly horizontal Paleozoic strata are cut by many intersecting faults, the faulted blocks being consequently of small size. The subject is of special interest from its bearing on the probable structure of the adjoining Adirondack mountain area of crystalline rocks.

The formation of lake basins by wind. G. K. GILBERT. Observations of lakelets on sterile Cretaceous shale of the plains crossed by the Arkansas river in southeastern Colorado.

The Tepee buttes. G. K. GILBERT and F. P. GULLIVER. Knolls 10 to 30 feet high, left by subaërial denudation where *Lucina* colonies existed in the Ft. Pierre shales, on a belt extending northward and eastward from near Pueblo, Colorado.

Remarks on the geology of Arizona and Sonora. W J MCGEE.

Geology of the Highwood mountains, Montana. WALTER H. WEED and LOUIS V. PIRSSON.

Genesis and structure of the Ozark uplift. CHARLES R. KEYES.

The geographical evolution of Cuba. J. W. SPENCER.

Recent glacial studies in Greenland. T. C. CHAMBERLIN. (Presidential address.)

Observations on the glacial phenomena of Newfoundland, Labrador, and southern Greenland. G. FREDERICK WRIGHT.

Highland level gravels in northern New England. C. H. HITCHCOCK.

Variations of glaciers. HARRY FIELDING REID.

Discrimination of glacial accumulation and invasion. WARREN UPHAM.

Climatic conditions shown by North American interglacial deposits. WARREN UPHAM.

Glacial lakes in western New York. H. L. FAIRCHILD.

Lake Newberry, the successor of lake Warren. H. L. FAIRCHILD.

Notes on the glaciation of Newfoundland. T. C. CHAMBERLIN.

The pre-Cambrian floor in the Northwestern states. C. W. HALL. From the records of deep and artesian well borings a series of sections and maps shows the extension of the pre-Cambrian rocks from their outcropping areas downward under the later formations to the successive depths of contours at the present sea level, and at 500 feet and 1,000 feet below that level.

A further contribution to our knowledge of the Laurentian. FRANK D. ADAMS. Description of an area of anorthosite and surrounding crystalline rocks of the Grenville series extending from the island of Montreal about 50 miles northward.

The crystalline limestones, ophiolites, and associated schists, of the eastern Adirondacks. J. F. KEMP. These limestones and schists, occurring in small areas, usually less than a square mile, are regarded as older than the gabbros and anorthosites of the Norian series, being probably the remnants of an extended formation which was cut up by the gabbro intrusions, metamorphosed largely by them, and afterward eroded.

The crystalline limestones and associated rocks of the northwest Adirondack region. C. H. SMYTH, JR.

Lower Cambrian rocks in eastern California. C. D. WALCOTT. The White mountain range, whose structural features were noted in the second paper of this list.

Devonian fossils in Carboniferous strata. H. S. WILLIAMS. In northern Arkansas, at Spring Creek, near Batesville.

The Pottsville series along New river, West Virginia. DAVID WHITE.

Stratigraphic measurement of Cretaceous time. G. K. GILBERT. Describing regular alternations of shale and limestone, in pairs of strata together mostly from one to three feet thick, occurring commonly throughout a great thickness of the Ft. Benton, Niobrara and Ft. Pierre shales in the Arkansas river basin. The hypothesis suggested for these alternations is dependence upon the astronomic cycles of precession of the equinoxes, which would require some 20,000,000 years for the deposition of this portion of the Cretaceous series, representing perhaps half of the Cretaceous period.

Notes on the Cretaceous of western Texas and Coahuila, Mexico. E. T. DUMBLE.

The Cretaceous deposits of the northern half of the Atlantic coastal plain. WILLIAM B. CLARK.

The marginal development of the Miocene in eastern New Jersey. WILLIAM B. CLARK.

Sedimentary geology of the Baltimore region. N. H. DARTON.

The surface formations of southern New Jersey. ROLLIN D. SALISBURY.

On new forms of marine algæ from the Trenton limestone, with observations on Buthograptus laxus *Hall.* R. P. WHITFIELD.

Spherulitic volcanics at North Haven, Maine. W. S. BAYLEY.

The peripheral phases of the great gabbro mass of northeastern Minnesota. W. S. BAYLEY. On the northern boundary of this great gabbro area are basic and granulitic rocks whose composition indicates their relationships with the gabbro. The basic rocks are aggregates of the basic constituents of the gabbro, and they are characterized especially by their abundance of titanic iron. The granulitic rocks differ from the minerals

of the gabbro mainly in structure. They consist of aggregates of rounded diallage, hypersthene, and plagioclase, all of which minerals are present also in the normal rocks. The basic rocks are regarded as probably differentiated phases of the gabbro, of earlier age than the great mass of the normal rock, while the granulitic phases are simply structural peripheral phases.

The contact phenomena at Pigeon point, Minnesota. W. S. BAYLEY. An exhibition of specimens.

The relation of grain to distance from margin in certain rocks. ALFRED C. LANE. Description of the variation in texture and grain of some quartz diabase dikes of the northern peninsula of Michigan, and comparison with effusive flows of similar mineral composition. Interstitial micropegmatite is primary or pneumatolytic, and the feldspar crystallization began before that of the augite, continuing until later. The main object of the paper was to elicit, by discussion, the best methods of measuring the coarseness of grain of a rock.

Crystallized slags from copper-smelting. ALFRED C. LANE. Describing (with exhibition of specimens) some slag from the cupola furnaces used in copper-smelting, with large melilite crystals, between one and two centimeters square, interesting optically and in mode of occurrence. Crystallized hematite is also noted.

On the honeycombed limestones in the bottom of lake Huron. ROBERT BELL. The limestones over a certain region in the bottom of this lake are ascertained by the fishermen to be extensively eroded in a peculiar manner which the writer calls honeycombing and pitting. This condition is ascribed to a differential solubility of the rock in the presence of slightly acidulated water.

On the nomenclature of the fine-grained siliceous rocks. LEON S. GRISWOLD.

On some dikes containing "huronite." ALFRED E. BARLOW. A petrographical notice of certain dikes of diabase north and northeast of lake Huron, containing "huronite," as the mineral was named by Dr. Thomson in 1836. It is found to be an impure or altered form of anorthite, which has undergone either partial or complete "saussuritization," owing to metamorphic action.

The characteristic features of the California gold quartz veins. WALDEMAR LINDGREN.

On the quartz-keratophyre and its associated rocks of the Baraboo bluffs, Wisconsin. SAMUEL WEIDMAN (introduced by W. H. Hobbs). In the vicinity of Baraboo, Wis., acid porphyritic rocks occur of pre-Cambrian age, which correspond chemically with quartz-keratophyres. They exhibit under the microscope fluxion, spherulitic, poikilitic, and other structures of volcanic rocks, and are associated with volcanic breccias which show them to have their origin in a surface flow.

The granites of Pike's Peak, Colorado. EDWARD B. MATTHEW (introduced by W. B. Clark). An areal and petrographical description of the granites composing the southern end of the Rampart or Colorado range, showing that great macroscopic variation may result while the microscopic characters remain monotonously uniform.

A new intrusive rock near Syracuse, New York. N. H. DARTON and J. F. KEMP.

On the decomposition of the granite rocks of the District of Columbia. GEORGE P. MERRILL.

Ancient physiography as represented in sediments. BAILEY WILLIS.

Serpentine pseudomorphs after olivine, formerly called quartz-pseudomorphs, Middlefield, Mass. B. K. EMERSON.

Skeleton crystals of salt which have been called chiastolite and later spinel, from the Trias, Westfield, Mass. B. K. EMERSON.

Radiating puckering of corundum crystals around allanite, Pelham, Mass. B. K. EMERSON.

THE AMERICAN GEOLOGIST
Vol. XV., Plate III.

THE

AMERICAN GEOLOGIST.

Vol. XV. FEBRUARY, 1895. No. 2.

GEORGE HUNTINGTON WILLIAMS.

1856-1894.

[Portrait.]

Itaque adolescentes mihi mori sic videntur, ut cum aquae multitudine flammae vis opprimitur.—Cato.

The student of organic nature, busied with the various forms under which life has manifested itself, frequently meets with phases of individual growth, among the living or in the earth's catacombs, which show that one creature may pass through its developmental changes more rapidly than its fellows, spanning structural chasms, leaping vales and scaling hights which others of its race must plod slowly and traverse with weary effort. In intellectual growth is the faithful parallel of such physical acceleration of development which the Greeks idealized in their concept of Athene, full-grown and accoutered at her marvelous birth; equipped for war, not robed for peace.

The geniuses of science, "standing on the mountain-top and catching the first rays of the rising sun," pregnant with new views of nature, have realized that the path to success must be hewn out with labor demanding the utmost of their equipment. Experience has written nothing more indelible than that for the loiterer, the dreamer, the man of leisure there is no niche in science.

In the death of professor Williams, who was a man of genius, of intellectual prowess and an unremitting laborer, it is difficult to fully apprehend the loss which has fallen to geo-

logical science in America. As the aged Cato is made to say, this life has been quenched, not permitted to burn out. At the very threshold of his prime, with all his powers symmetrically ripening, and in the promise of a future glorious to himself and the sciences he loved, he is stopped. The pang is such as rent the heart at the too early departure of Roland D. Irving and H. Carvill Lewis.

American geology is now called to mourn not simply because one of its workers has fallen by the way, but in that it has lost that rare product among its devotees, a well-rounded man of broad culture, wide interests and generous instincts, an investigator of astuteness and notable success, a teacher of magnetic fervor, a speaker of polished fluency and trenchant aptness. It is a loss we could ill afford, for which there seems now no compensation, from which none can reap a benefit and all suffer only bereavement. The key to the mystery is in the keeping of heaven.

Professor Williams died of typhoid fever on the twelfth of July last, at his childhood's home in Utica, N. Y. During the scorching days of early summer, while in the field upon the Piedmont plateau of Maryland, he drank freely of a germ-poisoned well. His system, tired and exhausted by the labors of the academic year, gave way to the attack which followed.

He was born at Utica, January 28th, 1856, and was, hence, in his thirty-ninth year. His father, Robert S. Williams, a prominent citizen of that city, a man of substantial and ennobling tastes, surrounded his three children, of whom our lamented friend was the eldest, with the refining influence of such interests, coupled with sturdy virtues drawn from a long line of Puritan heritage. As the writer knew it fifteen years ago, it was a home whence emanated only inspirations of the good, the beautiful and the true, where gentler influences reigned and where a mighty and well-selected library cast an irresistible charm.

No one could have held a livelier appreciation of such early advantages than did Williams himself, and while he accounted the lack of them in another no fault or necessary obstacle to success, he was quick to see that it was not without significance. Circumstances which would have left many another less keenly alive to the need of an active, vigorous employ-

ment, were to him a wholesome stimulus toward the best which life could afford.

He was of a fine nervous temperament, which, if it prevented a high degree of physical robustness, nevertheless infused both body and mind with activity. To many who knew him well it was a source of surprise that he endured so sturdily the often arduous strain of geological field work, and that it ever became to him a means of bodily repair and refreshment. Yet it was his mind that was normally and by nature more richly endowed than his body.

During his early training in the public schools of Utica, terminating with his graduation from the Utica Free Academy, he left traces all along of the first degree of excellence. In the autumn of 1874 he entered Amherst college. Here he showed the same proficiency in all lines of academic work, loving and excellent in the languages and their classics, stout in mathematics; the two essential ingredients of the first half of such a course. The former kindled a flame which was never allowed to die, and to these accomplishments must be due in no small degree, his broader and more delightful tastes.

I am not aware that Mr. Williams had manifested any especial aptitude for natural science during his boyhood; a respect in which he was like many who have attained eminence as investigators and philosophers in this field of knowledge. The rigors of his preliminary training and earlier college course may have afforded no opportunity for the development of such tastes, and the scientific instinct was dormant until he came into contact, in his junior year, with that devoted teacher, professor B. K. Emerson.

I recall his enthusiastic devotion to zoology (a subject which at that time came within the scope of professor Emerson's work), which seemed for him a door opening into a new world of interest. And when he touched the living rock and had become thoroughly enamored of geology, his fondness for its zoological side long clung to him.

Being graduated in 1878, a portion of the following year was spent at Amherst in post-graduate work. Petrography was then a virtually new science in this country. Zirkel, of Leipzig, had aroused an interest in the microscopical study

of rock-masses by his work for the United States Geological Survey when under the direction of Clarence King (1876), but there were then few American students in Germany imbibing this new knowledge, and as few at home to whom Zirkel's work appealed. In 1879 there were probably not a dozen men here who were making serious efforts in this new departure, but of these professor Emerson, alive to every phase of his science, was one. Mr. Williams' interest was enlisted under these influences, and he was led to seek, the following year, the well-springs of such knowledge at Göttingen and Heidelberg. Meanwhile, however, he returned for a brief period during the spring of 1879, to Utica and taught various sciences in the academy which he had left five years before. Though in this capacity but for two or three months, he infused such a degree of enthusiasm in his pupils for every subject he touched upon as to render the writer's task as his successor a difficult one. Emerson had graduated at Göttingen during the life-time of that versatile geologist, von Seebach, and to Göttingen he naturally sent his pupil. There Ehrenberg, thirty years before, had turned the microscope upon the rocks, searching for their minutest organisms; von Waltershausen had done his immortal work on volcanoes, and Klein, now of Berlin and the foremost of physical mineralogists, was then lecturing. Here in the winter and summer semesters of 1879-80 Williams heard these lectures by Klein and those by Hübner in chemistry. The next year he changed to Heidelberg, where was and is Rosenbusch, a name which increasing numbers of Americans delight to honor, and there was begun a friendship between instructor and pupil which death alone could interrupt. After two years of work, principally with this inspiring man, he went up for his examination in December, 1882, achieving his degree with honor.

Upon too many of the young Americans who throng the German universities the glamor of the doctorate exerts a palpably unwholesome influence. The title here passes for more than its face value and, unhappily, it matters little whence it comes. When a well-directed public sentiment shall have restored to its proper dignity the now disordered and cheapened title, *professor*, the doctorate may resume its appropriate subsidiary place. With Williams the attainment of this degree

was but the terminating incident of his course and the title was never unduly paraded.

Returning to his home directly upon its accomplishment, he found himself situated as many others have been, with abundant opportunity to find something to do. At this critical period in the life of every young man, when the first serious step in his career has to be taken, Dr. Williams did not find his way laid open for him by outside influences; the writer recalls his disappointment at the failure of an attempt to connect himself with the work of the Smithsonian Institution. Soon, however (March, 1883), he obtained a fellowship-by-courtesy at the Johns Hopkins University, at Baltimore. It was not such a position as a young man not without supplementary resources could afford to accept, nor was it, of itself, quite to the level of Dr. Williams' hopes, although it was to prove the stepping-stone to his most successful career in that institution; for in 1884 he was advanced to the title of Associate, becoming thereby a member of the academic staff; in 1885 he became Associate Professor, and in 1892, ordinary Professor of Inorganic Geology.

When Dr. Williams entered upon his work at this institution there had been no department of geology and the instruction given had been of the most desultory sort, a little in mineralogy and lithology having been attempted in connexion with the department of chemistry. Upon him devolved the organization of the department, and the high efficiency which it has now attained is due almost solely to the vigorous prosecution of his conception of what such a department in such a university should be. He was quick to acknowledge the warm espousal of all his efforts by president Gilman. The output of his academic work as embodied in his students has stamped a value upon it which cannot now, probably never can be estimated, but its success in the eyes of those who were watching him from positions of close association is expressed in the memorial minute adopted by the board of trustees and the academic staff of the university, in which they bear testimony to "his alert, inquisitive observation, the close judgment and sound reasoning which he brought to the interpretation of what he saw, his excellent power of statement, whether with voice or pen; his cultivated appreciation of lit-

erature; the energy, hopefulness, enthusiasm which he carried into his work and imparted to his associates; his genuine individual interest in his students: the friendliness and helpfulness of his relations to his colleagues and his readiness to coöperate in every worthy undertaking."

He who trains students insures his own immortality. The young geologists, quick with the inspiration caught from intercourse with this man, will be his best and perpetual memorial. They are not many, his career was too short; but through them his elevating ideas and clear purposes for his science will not be lost.

There is one phase of this career, the best of it, he himself would have said, that in which lay the poetry of his life, which must not be overlooked. This was his total and unreserved devotion to his home. It is the more fitting to mention this here as many of the readers of these pages have shared the hospitality and known the loveliness of that home. It was a spot where every geological worker was welcomed, whose entire resources were at the command of the scientific comer; and, to the students, the point where they came into closest touch with the personality of the teacher.

In 1886, Mr. Williams married Mary Wood, a daughter of the late Hon. Daniel P. Wood, of Syracuse, N. Y., a man widely known for his accomplishments in law and statecraft, and whose appreciation of science was evinced, during his long career in the legislature of his state, by the generous and unflinching support which he accorded to the work of its geological survey under professor James Hall. The marriage brought about one of those rare relationships in which the work of the man found at once its most appreciative coöperation and support, and its most rigorous critic, in the intellectual intuitions of the woman. The value of such companionship, not alone to the worker, but to his work, is not often overestimated. In his peripatetic work she was often his companion, accompanying him among the hills of Maryland and upon his Norwegian trip with Prof. Rosenbusch and Dr. Reusch; and in the study she was his first and acutest auditor. Three sons were born into this home, two of whom still live, one of them bearing his father's name.

It is not possible in this place to give an extended analysis

of professor Williams's published work; that may be reserved for another occasion and writer. Here its results and conditions are briefly summarized.

During his university life in Germany, in the interval between his semesters at Göttingen and Heidelberg, Mr. Williams made a tour of southern and southeastern Europe, bringing back with him the materials for his first scientific publication, "Glaukophangesteine aus Norditalien," which was printed in the Neues Jahrbuch für Mineralogie in 1882. This was followed in 1883 by his inaugural dissertation, published in the same journal, on the Eruptive Rocks of the vicinity of Tryberg in the Black Forest, an elaborate investigation which elicited the applause of geologists best able to appreciate it.

The work of a geologist is preëminently what his environment makes it; hence with Dr. Williams' return to America and the commencement of his work at the Johns Hopkins University his attention was directed to geological problems presented by the region about him. In 1884 he began a series of papers pertaining to the petrography of the vicinity of Baltimore, publishing two in that year and continuing them for nearly ten years. Twenty papers and maps published during this period may be regarded as pertaining to this subject, and the outcome of his geographical location. Many of the briefer of these papers appeared in the University Circulars, a mode of publication in which the author evinced his patriotism for his patron institution, even at the risk of hiding his work from a great part of the interested world. But under the auspices of the United States Geological Survey, with which he became connected soon after his appointment at Johns Hopkins, he was enabled to elaborate his results in detail, publishing in 1886 an important bulletin (No. 28) on the Gabbros and associated Hornblende Rocks occurring in the neighborhood of Baltimore. In his Guide to the Crystalline Rocks of Baltimore and vicinity, prepared for the meeting of the American Institute of Mining Engineers in that city in 1892, the geological map of Baltimore and vicinity, published by the University in 1892, the Baltimore sheet prepared in collaboration with Nelson H. Darton, for the Geologic Atlas of the United States, professor Williams was ena-

bled to summarize the main results of his labors in that region. Immediately connected with this work was the series of highly important investigations upon the volcanic rocks of the South Mountain, published in 1892 and 1893, which demonstrated the existence in that region of eruptives in all respects like those of recent origin.

Another valuable series of papers embraces those which pertain to the petrography, mineralogy and crystallography of his native state, New York, the materials for which were largely gathered during the intervals of his academic work. We find fourteen of these extending over a period of six years (1884-1890), among the more important of which are those relating to the petrography and contact-effects in professor Dana's "Cortlandt Series" on the lower Hudson; and four papers on the serpentine dike at Syracuse, discovered by Vanuxem about 1840, but lost sight of for nearly a half-century after.

The vacation periods of 1884 and 1885 were spent in northern Michigan and the results of his work there were expressed in an exhaustive treatise on the Greenstone-schist areas of the Menominee and Marquette regions, published as bulletin No. 62 of the United States Geological Survey (1890). Among his other special papers we find one bearing on the geology of the island of Fernando de Noronha, two on the rocks of the Sudbury District, Canada, one on rocks from Alaska and another on the crystallines of the Andes.

At the close of the London meeting of the International Congress of Geologists, in 1888, professor Williams joined his instructor, Rosenbusch, in a visit to the crystalline regions of Norway, under the guidance of Dr. Hans Reusch, whose investigations upon areal metamorphism have made those regions famous. Though he produced but a single brief paper upon the results of this trip, yet its effects were undoubtedly far reaching upon his subsequent work.

In all these papers his writing is characterized by its lucidity and incisiveness, its freedom from contentiousness and its generous tolerance of adverse opinion. There was nothing bellicose in his composition and he never penned a polemic.

The value of his services to his science cannot be estimated alone from these technical papers in his special field of activ-

ity. He brought himself into contact with the intelligent public in several general expositions of the broader bearings of his interests, such as his two articles on the relation of the microscope to the study of the rocks, published in "Science," and a more extended presentation of Some Modern Aspects of Geology, in the "Popular Science Monthly." And of wider influence as well as of standard importance is his "Modern Petrography," published in 1886, as the first of a series of "Monographs on Education," issued by Heath, of Boston. His "Elements of Crystallography" (1890), written to supply the needs of his own pupils, has become widely adopted in institutions of higher education in America and is understood to have already passed through several editions.

His mechanical ingenuity and adeptness were shown in his design for the petrographical microscope constructed by the Bausch-Lomb company and which has long been hatched upon the cover-page of this journal; and also in the invention of a machine for cutting and grinding thin rock-sections, of which the motive power is electricity. Of this useful contrivance he published a description in the American Journal of Science for February, 1893.

Even to this young man the honors which beautify and crown success were beginning to come. He had been made a vice-president of the Geological Society of America, a corresponding member of the Geological Society of London and a member of the Mineralogical Society of France. Under the auspices of the Maryland board of managers of the World's Fair Commission he was given charge of the preparation of the state book, and in conjunction with his associate, professor W. B. Clark, prepared the geological part of that work. Under similar auspices he served as one of the judges of award in the Department of Mines and Mining at the World's Fair, and the last paper but one published by him was an account of the exhibits in mineralogy and petrography, which appeared in the GEOLOGIST for May, 1894.

Professor Williams's early departure has terminated one of those truest lives which Dr. Holmes characterized as like a rose-cut diamond, with many facets answering to the many-planed aspects of the world about it; its influence elevating, its memory sweet.

JOHN M. CLARKE.

LIST OF THE PUBLISHED WORKS OF PROF. GEORGE H. WILLIAMS.

(The main portion of this list is taken from the *Bibliographia Hopkinsiensis*, issued in 1893.)

Glaukophangesteine aus Nord-Italien. Neues Jahrbuch für Min., etc., 1882, II, p. 202.

Die Eruptivgesteine der Gegend von Tryberg im Schwartzwald. Inaugural dissertation. Ib., Beilage-Band II: pp. 585-634. 1883.

The synthesis of minerals and rocks. Review of Fouqué et Michel-Lévy's "Synthèse des minéraux et des roches." Am. Chem. Jour., V, p. 127.

Relations of crystallography to chemistry. Am. Chem. Jour., V, p. 461.

Barite crystals from DeKalb, N. Y. Univ. Circ., 29, March, 1884, p. 61.

Preliminary notice of the gabbros and associated hornblende rocks in the vicinity of Baltimore. Ib., 30, April, 1884, p. 79.

Note on the so-called quartz-porphyry of Hollins Station, north of Baltimore. Ib., 32, July, 1884, p. 131.

On the paramorphosis of pyroxene to hornblende in rocks. Am. Jour. Sci., XXVIII, pp. 259-268, October, 1884.

Notice of J. Lehmann's work on the origin of the crystalline schists. Proc. Am. Assoc. Adv. Sci., XXXIII, p. 405.

Review of J. Lehmann's "Entstehung der altkrystallinen Schiefergesteine." Am. Jour. Sci., XXVIII, p. 392, November, 1884.

Dykes of apparently eruptive granite in the neighborhood of Baltimore. Univ. Circ., 38, March, 1885, p. 65.

The microscope in geology. Science, V, March, 1885.

Hornblende aus St. Lawrence Co., N. Y.; Amphibol-anthophyllit aus der gegend von Baltimore: Ueber das Vorkommen des von Cohen als "Hudsonit" bezeichneten Gesteins am Hudson Fluss. Neues Jahrbuch für Min , etc., 1885, II, p. 175.

Cause of the apparently perfect cleavage in American sphene. Am. Jour. Sci., XXIX, pp. 486 490, June, 1885.

A summary of the progress in mineralogy and petrography in 1885. Reprinted from the Am. Naturalist for 1885.

The peridotites of the "Cortlandt Series" near Peekskill on the Hudson river, N. Y. Am. Jour. Sci., XXXI, pp. 26-41, January, 1886.

The gabbros and associated hornblende rocks occurring in the neighborhood of Baltimore, Md. Bulletin U. S. Geol. Survey, No. 28, Washington, 1886; 78 pp. and 4 colored plates.

Modern petrography. Heath's Monographs on Education, No. 1, 35 pp., Boston, 1886.

On a remarkable crystal of pyrite from Baltimore Co., Md. Univ. Circ. 53, November, 1886, p. 30.

The norites of the "Cortlandt Series" on the Hudson river, near Peekskill, N. Y. Am. Jour. Sci., 3, XXXIII, pp. 135-144 and 191-199, February and March, 1887.

On the chemical composition of the orthoclase in the Cortlandt norite. Ib., p. 243.

On the serpentine of Syracuse, N. Y. Science, IX, p. 232, March 11, 1887.

On the serpentine (peridotite) occurring in the Onondaga salt-group at Syracuse, N. Y. Am. Jour. Sci., XXIV, pp. 137-145; August, 1887.

Holocrystalline granite structure in eruptive rocks of tertiary age. (Review of Stelzner's "Beiträge zur Geologie der Argentinischen Republik.") Ib., XXXIII, p. 315, April, 1887.

Notes on the minerals occurring in the neighborhood of Baltimore. Baltimore, 1887, 18 pp.

Note on some remarkable crystals of pyroxene from Orange Co., N. Y. Am. Jour. Sci., XXXIV, p. 275, October, 1887.

Rutil nach Ilmenit in verändertem Diabas. Pleonast (Hercynit) in Norit vom Hudson-Fluss. Perowskit in Serpentin (Peridotite) von Syracuse, N. Y. Neues Jahrbuch für Min., etc., 1887, II, pp. 263-267.

On a new petrographical microscope of American manufacture. Univ. Circ., 62, p. 22, January, 1888; Am. Jour. Sci., XXXV, p. 114, February, 1888.

On a plan proposed for future work upon the geological map of the Baltimore region. Univ. Circ., 59, p. 122, August, 1887.

Progress of the work on the Archæan geology of Maryland. Ib, No. 65, p. 61, April, 1888.

The gabbros and diorites of the "Cortlandt Series" on the Hudson river near Peekskill, N. Y. Am. Jour. Sci., XXXV, p. 438-448, June, 1888.

The contact-metamorphism produced in the adjoining micaschists and limestones by the massive rocks of the "Cortlandt Series" near Peekskill, N. Y. Ib., XXXVI, pp. 254-269, plate VI, October, 1888.

Geology of Fernando de Noronha. Part II. Petrography. Ib., XXXVII, pp. 178-189, March, 1889.

On the possibility of hemihedrism in the monoclinic crystal system, with especial reference to the hemihedrism of pyroxene. Ib., XXXVIII, pp. 115-120, August, 1889.

Contributions to the mineralogy of Maryland. Univ. Circ., 75, p. 98, September, 1889.

Some modern aspects of geology. Popular Science Monthly, September, 1889.

Note on the eruptive origin of the Syracuse serpentine. Bulletin Geol. Soc. Amer., I, p. 533.

Geological and Petrographical observations in southern and western Norway. Ib., pp. 541-553.

Celestite from Mineral Co., West Virginia. Am. Jour. Sci. XXXIX, pp. 183-188, March, 1890.

Same reprinted in German in Zeitschr. Kryst. u. Min., XVIII, p. 1, 1890.

On the hornblende of St. Lawrence Co., N. Y., and its gliding planes. Am. Jour. Sci., XXXIX, pp. 352-358, May, 1890.

The non-feldspathic intrusive rocks of Maryland and the course of

their alteration. First paper. The original rocks. AM GEOLOGIST, July, 1890, VI, p. 35.

Elements of crystallography for students of chemistry, physics and mineralogy. New York, H. Holt & Co.; 8vo, 250 pp., 383 figures and 2 plates.

The greenstone-schist areas of the Menominee and Marquette regions in Michigan. Bull. U. S. Geol. Survey, No. 62, 241 pp., 29 figures and 16 plates, Washington, 1890.

The silicified glass-breccia of Vermilion River, Sudbury district. Bull. Geol. Soc. Amer., II. p. 138.

The petrography and structure of the Piedmont plateau in Maryland. Ib., pp., 301-318.

Anglesite, cerussite and sulphur from the Mountain View lead mine, near Union Bridge, Carroll Co., Md. Univ. Circ., 87, April, 1891. Octavo, reprint.

Anatase from the Arvon slate quarries, Buckingham Co., Va. Am. Jour. Sci., XLII, p.431, November, 1891.

Notes on the microscopical character of rocks from the Sudbury mining district, Canada. Appendix I to Dr. R. Bell's paper on the Sudbury mining district. Rep. Geol. and Nat. Hist. Survey of Canada, 1888-1890. F, pp. 55-82.

Notes on some eruptive rocks from Alaska. Appendix to Prof. H. F. Reid's paper on the Muir glacier. Nat. Geog. Mag., IV, pp. 63-74.

Geological excursion by University students across the Appalachians in May, 1891. Univ. Circ., 94, December, 1891.

A university and its natural environment. Address before the Johns Hopkins University. Ib., 96, March, 1892.

Crystals of metallic cadmium. Am. Chem. Jour., XIV, p. 274.

Geology of Baltimore and vicinity. Part I. Crystalline rocks. Guide-book for Am. Inst. Min. Engineers, Baltimore, February, 1892, pp. 77-124.

Geological map of Baltimore and vicinity. Published by the Johns Hopkins University, G. H. Williams, Editor, October, 1892.

The volcanic rocks of South Mountain in Pennsylvania and Maryland. Am. Jour. Sci., XLIV, pp. 482-496, December, 1892. Reprinted in "Scientific American," January 14, 1893, and abstract Univ. Circ., 103.

The microscope and the study of the crystalline schists. Science, January 6, 1893.

A new machine for cutting and grinding thin sections of rocks and minerals. Am. Jour Sci., XLV, p. 102, February, 1893, and Univ. Circ., 103.

Maps of the territory included within the state of Maryland, especially the vicinity of Baltimore. Univ. Circ., 103, February, 1893.

On the use of the terms poikilitic and micropoikilitic in petrography: Jour. of Geology, I, No. 2, p. 176, February, 1893.

Piedmontite in the acid volcanic rocks of South Mountain, Pennsylvania. Am. Jour. Sci., XLVI, p. 50, July, 1893.

Crystalline rocks from the Andes. Jour. of Geology, I, No. 4, p. 141, 1893.

Johann David Schoepff and his contributions to North American geology. Bull. Geol. Soc. Amer., 1893, pp. 591-594.

Mines and minerals of Maryland. Maryland World's Fair Book, 1893.

Piedmontite and Scheelite from the ancient Rhyolite of South Mountain, Pa. Am. Jour. Sci., July, 1893, vol. XLVI, p. 50

Recent contributions to the subject of dynamo-metamorphism. Jour. of Geology, vol I, p. 580. 1893: review.

The distributiou of ancient volcanic rocks along the eastern border of North America. Jour. of Geology, vol. II, No. 1, pp. 1-31, pl. 1, 1894.

Sixth annual excursion of the Geological Department. Univ. Circ., 109, p. 26, February, 1894.

The Columbian Exposition. Notes on various exhibits relative to mineralogy and petrography. AM. GEOLOGIST, vol. XIII, No. 8, pp. 345-353, May, 1894.

On the natural occurrence of Lapis-Lazuli. Univ. Circ., 114, p. 111, July, 1894.

Sixty-eight reviews of American geological and petrographical literature, published in the Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie, between 1884 and 1890.

The Williams family, tracing the descendants of Thomas Williams, of Roxbury, Mass. N. Eng. Hist. Reg., 1880. Reprinted for private distribution.

—— and W. M. Burton.

On the crystal form of metallic zinc. Am. Chem. Jour., XI, No. 4.

—— and Wm. B. Clark.

Geology and mineral resources of Maryland, with geological map. In the book "Maryland," published by the State Board of Managers for the World's Fair Commission, July, 1893.

—— and N. H. Darton.

Baltimore Atlas Sheet. Geologic Atlas of the United States, U. S. Geol. Survey.

THE GEOLOGIC HISTORY OF MISSOURI.*

By ARTHUR WINSLOW, St. Louis. Mo.

Introduction.—The geology of Missouri has now been studied for a period of half a century. Though much detail yet remains to be worked out, its general features are known; the periods to which the formations belong have, in the main, been determined and their structure is understood. We are, therefore, in a position to narrate with some confidence many facts of the geologic history of the state. In the present state of our knowledge of such a complicated subject, it is, however, not always possible to make positive statements. But, in such cases, much can be said which is at least sug-

*Read by title at the Brooklyn meeting of the Geological Society of America, Aug., 1894.

gestive and which may be profitable in directing future inquiry.

Before proceeding to the subject proper a few remarks will be in place concerning the classification of the rocks and the distribution of formations. In the following table is presented a scheme which is the outcome of recent work by the writer and associates of the State Geological Survey.

The names and the divisions of this scheme differ in several respects from those previously published. We will not attempt here to give the reasons for these changes. They will appear in the forthcoming report of the Geological Survey on the lead and zinc deposits of the state, now being printed. We shall use this classification and nomenclature in the following discussion.

Distribution.—The Archean rocks of Missouri occur exclusively in the southeastern part of the state. They are confined principally to an area of about 2,000 square miles, situated less than 80 miles south of St. Louis and less than 50 miles west of the Mississippi river. They consist essentially of porphyries and granites, composing a group of hills named the St. Francois mountains.

The Lower Silurian (and possible Cambrian) rocks of the Ozark stage surround these Archean crystallines on all sides. They extend eastward nearly to the Mississippi river, northward to the Missouri, excepting in the vicinity of St. Louis, westward to within 50 miles of the Kansas line, and southward beyond the border of the state. They consist principally of magnesian limestones and sandstones.

The Trenton and higher Lower Silurian formations are seen to overlie the Ozark formation only over a small area south of St. Louis and along the Mississippi river. Over the whole western portion of the state they are absent. They consist mainly of magnesian limestones.

Upper Silurian strata are absent in the state, with the exception of a few exposures in the east, adjacent to the Mississippi.

Devonian rocks are sparsely represented in the eastern and northeastern portions of the state. Neither the thickness or area is anywhere great. A few isolated patches are found along the Missouri river, on the north side. In the west the

CLASSIFICATION OF MISSOURI ROCKS.

			SOUTHWEST MISSOURI.	SOUTHEAST MISSOURI.	CENTRAL MISSOURI.
Carboniferous.	Coal Measures.	Upper. Middle. Lower.			
	Lower Carboniferous.	Kaskaskia.			
		St. Louis.			
		Augusta.			
		Kinderhook.			
Devonian.			Eureka shale.	Hamilton. Onondaga limestone. Oriskany sandstone.	Absent.
Silurian.	Upper Silurian.		Absent.	Lower Helderberg.	Absent.
				Niagara.	
				Cape Girardeau limestone.	
		Trenton.	Absent.	Hudson River shale.	Absent.
				Receptaculites limestone.	
				Trenton limestone.	
	Lower Silurian.	Ozark.	White River limestone, including several beds of sandstone.	Joachim limestone.	Roubidoux or —Saccharoidal sandstone.
				Crystal City limestone.	
				St Francois limestone: Potosi limestone.	Gasconade limestone: Jefferson City limestone.
				St Francois limestone: St. Joseph limestone.	Gasconade limestone: Moreau sandstone.
					Gasconade limestone: Osage limestone.
					Gasconade limestone: Cole Camp sandstone.
				La Motte sandstone.	Gasconade limestone: Proctor limestone.
				Iron Mountain conglomerate.	
Cambrian.	Doubtfully present.				
Algonkian.	Pilot Knob beds.				
Archean.	Porphyries and Granites of the St. Francois mountains.				

By Southwest Missouri is meant the western half of the state south of the Missouri.
By Southeast Missouri is meant the eastern border of the state, south of the Missouri river, a strip about 50 miles broad.
By Central Missouri is meant a strip about 50 miles broad, extending south from the Missouri river and lying between the southeastern and southwestern districts.

only Devonian rock (and this is doubtfully assigned to that age) is the Eureka shale, which is a stratum of black shale, varying fron 10 to 60 feet in thickness. It is found only in the extreme southwestern corner and there lies between the magnesian limestones of the Ozark stage and the Lower Carboniferous rocks.

Lower Carboniferous limestones and shales in great thickness are exposed over wide areas in the northeastern, central and western sections. They are generally in direct contact with beds of the Ozark stage. Sometimes, Devonian and higher Silurian strata intervene.

The Coal Measures cover the whole northwestern, and a broad strip in the southwestern portions of the state. They rest unconformably upon the Lower Carboniferous and extend beyond the limits of the latter formation.

From this brief description it will be seen that the rocks of the different formations surround the Archean nucleus in a somewhat concentric form, though the sequence is broken in many places. This center is geologically a quaquaversal arch which has been raised and depressed several times. It is well known as the Ozark uplift.

With these explanatory remarks we will now proceed to describe the conditions which prevailed and the noteworthy events which took place during the different geologic eras or periods, beginning with the oldest.

The Archean Era.—The Archean land surface of this portion of the globe must have been a very extensive one. At the beginning, at least, it probably spread well beyond the state limits. Its original outlines are at present undefinable, but, from the fact that the rocks of the present land must originally have been derived in large part from these pre-existing Archean rocks, the mass exposed to denudation must have been very great.

The Algonkian Era.—Before the end of the Algonkian era the Archean land surface of Missouri was entirely submerged. Whether this condition was reached during the late Algonkian or during the early Algonkian we are unable to say. Probably there was a gradual lowering, such that complete submergence was not accomplished till towards the end. The extent of the Algonkian deposition is unknown and

minable. The only considerable exposure at present is the small patch on Pilot Knob. Possibly, rocks of the same formation are represented under the surrounding Paleozoic beds; of this, however, there is no positive evidence, excepting, perhaps, in the record of a deep drill hole put down at Raytown, south of Kansas City. Here the base of the Paleozoic rocks was reached at a depth of 2,430 ft., and below this 36 ft. of crystalline rocks were penetrated. A specimen of this core examined by the writer, is a highly micacious schist, composed almost entirely of black mica. It is different from any rocks found in the Archean of the southeast and is more like rock referred to the Algonkian elsewhere. A drill hole at the St. Louis insane asylum 3,600 ft. deep, one at Carthage about 2,000 ft. deep and one near Sullivan, Franklin county, about 1,200 ft. deep, all reached crystalline rock. In the first, the rock is reported by Prof. Broadhead to have been granite; in the second, Mr. J. D. Robertson determined the specimens to be porphyry; in the third, drillings examined by the writer consisted of pink feldspar and quartz like those of the Archean granites. These last results, therefore, are opposed to the existence of Algonkian rocks at the respective localities, though such may have existed there in the past and have since been removed.

The Cambrian Period.—During the Cambrian period, Missouri was probably a land surface, at least in large part. This conclusion is reached: first, because there are either only a very limited thickness or no rocks of this age in the state; and second, because there is evidence of a very great erosion between the Algonkian era and the Silurian period. During this interval all but the small Pilot Knob patch of Algonkian beds were entirely removed and the underlying Archean granites and porphyries were deeply trenched. It is to this date that we must assign the original sculpturing of the hills and valleys of southeastern Missouri, around and between which the Silurian limestones are now spread. To have eroded this great mass of resistant Algonkian and Archean rocks must certainly have taken a long period, even geologically considered. Possibly, this elevation and erosion may have begun well back in the Algonkian time and have continued through the Cam- [illegible] This would make the maintenance of the conditions

of emergence still longer and would make the almost complete removal of the Algonkian beds more readily understood. It is, however, possible that this land surface was only about the St. Francois mountains, and that Cambrian beds now exist in the deep basins away from here, especially to the northeast. Of this we have no local evidence to present, however.

The Silurian Period.—Early in the Silurian, or possibly before the end of the Cambrian, well nigh the whole of Missouri must have been submerged and the deposition of the rocks of the Ozark stage was begun. Before the end of the Lower Silurian epoch it is probable that a re-elevation took place, exposing a large land surface to erosion. We conclude this because we are of the opinion that the Trenton and higher Silurian strata never covered the whole Ozark area. There is no positive evidence of their former existence there. The absence of any remnant or outlier, and also the absence of these rocks between the Devonian and Lower Silurian formations of the extreme southwest are both facts opposed to the idea of this extension. The same applies to the Crystal City sandstone, though to a less degree. Lithologically this formation has more the character of a fluvial or estuary deposit than of a wide spread sandy stratum. The flow structure or false bedding frequently exhibited is in harmony with this idea. The unconformity with underlying rocks, exhibited at many localities, shows that an erosion period preceded its deposition.

At the end of the Silurian period most of southern Missouri or of the Ozark uplift was, without much doubt, well above water level.

The Devonian Period—appears to have been essentially one of emergence in southern Missouri and to have remained so throughout. As with the Trenton and Upper Silurian strata, there is no positive evidence, in the nature of outliers or residuary products, of the former presence of Devonian rocks over the Ozarks. Along the western border of the uplift the formation is also absent between the Ozark stage of the Lower Silurian and the overlying Lower Carboniferous strata, with the exception of where the Eureka shale comes in, in McDonald county. Similarly, they are absent along most of the

eastern border, while along the northern border they occur in limited patches, as if filling estuary-like depressions in the margin of an old land mass. This, therefore, we also class as a long erosion period, during which the Ozark rocks were extensively denuded and perhaps even base leveled. During this interval the inequalities of the surface were produced which caused the oft observed unconformity of contact with the later deposited Lower Carboniferous beds.

The Lower Carboniferous Epoch.—At the beginning, and possibly before, the waters crept in over the uplift, seizing hold of the insoluble products of sub-aërial decay of the Silurian rocks to make shales, sandstones and chert conglomerates, filling in great erosion depressions with these and dissolving the lime to assist in the formation of the Lower Carboniferous limestones. This movement continued doubtless for a long time, though at a very slow rate. From the fact that fragments of Lower Carboniferous chert are found over the surface so far into the interior as Howell and Crawford counties, the waters must have reached that far. Whether they extended beyond this, to the Archean area, is doubtful No remains of these rocks are found there. It is probable however, that estuary-like arms from the Illinois Carboniferous reached westward into Missouri.

It is further probable that the submergence of the central portion of the Ozarks did not last long, that only a thin stratum or somewhat isolated patches of rock were formed which were quickly and readily removed later. The mass of the rocks were doubtless deposited around the flanks and ran out to a feather edge toward the interior.

Well before the end of the Lower Carboniferous the uprise began and continued, probably, until almost all of southern Missouri became a land surface. A long continued period of emergence followed this, during which denudation must have been very vigorous. The surface became deeply trenched and covered with residuary materials. This caused the unconformity of the overlying Coal Measures and supplied abundance of material for the fragmental rocks which are at the base of that series.

The Coal Measure Epoch.—Early, probably at the beginning of the epoch, a renewed submergence and sequence of

events took place, similar to those immediately preceding the deposition of the Lower Carboniferous rocks. The waters again crept inland and upland, availing themselves of the products of sub-aërial decay for the making of new sediments, such as shales, sandstones, and chert conglomerates or boulder beds. These soon filled the depressions and spread themselves over the surface. The submergence probably did not extend so far inland as that of the Lower Carboniferous epoch. It was doubtless, however, well beyond the present Coal Measure margin. Outliers and coal pockets in the interior counties indicate a wide extension, but some of these could have been, and probably were, formed in inland lagoons. That they are sometimes surrounded by Silurian rocks shows that Lower Carboniferous or other intervening strata, if ever present at such points, had been removed prior to the Coal Measure deposition. This epoch, though one of fluctuating movements, was, on the whole, characterized by a sinking of the area surrounding the Ozark uplift. A reversal of the movement, inaugurated the Mesozoic.

The Mesozoic Era.—With this era we have little to do. No rocks of this formation are represented in the state. At the beginning, all of Missouri was above sea level for the first time and has continued so ever since, with the exception of the Mississippi embayment. This era is noteworthy, however, as marking the beginning of the present drainage system of the state. Heretofore, during various uplifts, a radial drainage from the center of the dome was undoubtedly developed, to be obliterated with each succeeding submergence. With the post-Carboniferous uplift, the Mississippi valley was first defined, as a result of the Cincinnati and Ozark uplifts; while the Missouri river valley appeared as the result of these and of the Wisconsin uplift. The present drainage began with a radial flow of water from the center of the Ozarks. Traces of this are still seen in the distribution of the streams of that area. At the beginning, the Missouri river was probably only rudimentary, its head being within, or at least not very far beyond, the western border of the state. This was so, because a divide must have existed in western Missouri or eastern Kansas, beyond which the waters flowed westward into the Mesozoic seas.

The Tertiary Epoch.—The conditions of Mesozoic stream trenching, land sculpturing and sub-aerial decay probably continuéd well into the Tertiary epoch. Then, with the uplift of the western country, a great change in the drainage took place; divides were transferred westward to the Rocky mountains, and the Missouri river assumed something of its present proportions. It was probably somewhere about this time that the partial over-flow or great rise of the waters of southwestern Missouri took place, producing the deposits of gravel which are found along Spring river and other streams. All of the Ozark area proper, however, continued above water level and has, since that time, been subjected uninterruptedly to denudation.

Conclusions.—Among the more important facts brought out in this sketch are the long periods of sub-aërial decay to which the Ozark area has been subjected, especially the one since the post-Carboniferous uplift. The surprising thing is that the whole country has not been completely base leveled. Changes of level have doubtless prevented it in part; but, in addition, the comparatively gentle slopes and the low altitudes and the absence of glacial action have supplemented this. The residuary products of decay have thus accumulated over the flat surfaces to great depths and they have protected the underlying rocks. The limestones, it is true, are not specially resistant, but the associated chert beds have shielded these. Further, from the fact that the climate was not arid and that the country is not and has not been at a great altitude, the surface has been well covered with vegetation. The declivities of the larger streams have not been great enough for them to corrade rapidly. To these causes we attribute the lasting qualities of this region.

The earth movements which took place were apparently of the nature of great pulsations, alternately raising and lowering the surface. Along the eastern border, a sharper monocline was developed, as is exhibited in the comparatively steep dips of eastern Ste. Genevieve county. This feature accounts for the greater declivities of the streams toward the east and the proximity of the divides to the Mississippi river. The presence of the Archean rocks so near the surface here, doubtless had its influence in locating this flexure.

A NEW CRETACEOUS GENUS OF CLYPEASTRIDÆ.

By F. W. CRAGIN, Colorado Springs, Colo.

The family *Clypeastridæ* makes its first appearance in the upper Cretaceous, and with forms which, so far as hitherto known, are of diminutive size and belong to the genera *Echinocyamus* and *Fibularia*. Eocene representatives of this family are also mainly of small size, though averaging larger than the Cretaceous. It is in the Miocene that large-sized clypeastrids, like *Clypeaster* and *Scutella*, first become abundant, though Eocene representatives of the former genus are known in Italy and elsewhere.

The discovery of a large-sized clypeastrid, bearing points of resemblance to both *Clypeaster* and *Scutella*, in the upper Cretaceous, is therefore of considerable interest.

The only known example of this clypeastrid is in the writer's private collection of Cretaceous Invertebrata. It is the type not only of a new species but of a new genus also; and these may be described as follows:

Scutellaster, gen. nov.

Clypeastrid large, combining the flattish-convex, or discoidal, test of *Scutella* with the pentagonal outline of *Clypeaster*; disc without loop-holes or any emarginations other than shallow convexities; ambulacral petals closed, or nearly so.

Scutellaster cretaceus, sp. nov.

Test as large as that of a large *Scutella*, or that of one of the more moderate-sized species of *Clypeaster*, obtusely pentagonal, its hight apparently about equal to, or not more than, one-tenth of its length; ambulacral petals of moderate breadth, reaching to within a short distance of the ambitus, the unpaired and anterior paired petals being straight, the posterior paired ones slightly sinuous; breadth of a pore belt (apparently) about half that of a semiambulacrum, the part of the ambulacrum between the pore-belts ornamented with light-colored puncta (the supposed spine-scars) arranged in quincunx; interambulacral plates thick, separated by deep sutures that are made especially pronounced by the beveled borders of the plates, the adambulacral half (on distal plates, less than half) of each plate being crossed with slightly raised, parallel curved lines, which subtend the borders of the ambu-

lacral petals and between which are puncta that, like those of the ambulacral mid-areæ, present the appearance of filled pores and are in quincunx, though forming a simple linear series between each two lines; surface of inner, or contiguous, halves of interambulacral plates, plain (or at least without lines, and with only minute puncta, which, in the type-specimen, are mainly obliterated), save near the ends where a number of coarse puncta are so arranged as to constitute a narrow and indefinitely bounded miliary zone.

Between the anterior and either antero-lateral angle, the outline of the test, as viewed from above, presents two trifling concavities separated by a broader convexity. Between either antero-lateral angle and the posterior angle of the same side, the outline presents a broad and shallow concavity which culminates opposite the anterior part of the posterior row of plates of that interambulacral field. The bottom of the test is not shown in the type, and the posterior border is imperfect, so that the exact form of the latter and the exact position, etc., of the peristome and periproct are unknown.

Measurements.—Length of test 105, breadth 83, hight (approximately) 8–10 mm.

Occurrence.—Preserved in a concretion weathered out of the arenaceous shale of the Fox Hills division of the Cretaceous, on the east slope of Shook's Run, on Platt avenue, Colorado Springs, Colorado.

The specimen was collected by Miss Anna Hetherington, and by her kindly presented to the writer, who is also indebted to Prof. Geo. H. Stone for his first knowledge of the find.

The writer believes that the genus *Scutellaster* may fairly be regarded as a *synthetic*, or *generalized*, type from which have been evolved *Scutella* on the one hand and *Clypeaster* on the other.

FURTHER OBSERVATIONS ON THE VENTRAL STRUCTURE OF TRIARTHRUS.

BY CHARLES E. BEECHER, New Haven, Conn.

(PLATES IV AND V.)

In previous papers on the ventral structure of *Triarthrus*, the anterior antennæ, thoracic legs and appendages of the

pygidium have been described.* There yet remain for investigation the appendages of the head and additional details of other parts of the animal. These characters have not been easily obtained on account of the labor of removing the rock from such delicate structures. Moreover, but few specimens are in the proper position or condition to yield satisfactory results. The appendages of the head either suffered greater decomposition than those of the thorax, before mineralization, or were so tenuous as to be easily obliterated, and are now seldom sufficiently well preserved for study. Further, the number and compact arrangement of such complicated organs, even when present, make it difficult to trace their precise form. A similar difficulty would be experienced were one to endeavor to describe the appendages of *Apus* by examining the ventral side without cutting away some of the limbs or at least unfolding or bending them around.

The features described in the present paper have been obtained by further work on the material secured for the Yale Museum, by professor Marsh. No detailed review of the ventral anatomy of *Triarthrus* will be given at this time, only such additional characters as have been observed since the publication of the last paper on this trilobite. The precise structure and relations of the organs here described must also be left subject to slight modifications required by researches which are still in progress. The writer has carefully prepared the specimens and made the drawings from camera lucida outlines. The appendages, however, are often so faintly preserved or so obscure that in order to represent them in a pen-drawing it is necessary to emphasize their limits and their prominence, and this may sometimes lead to errors of interpretation. It seems almost unnecessary to state that errors are not due to any preconceived notions of trilobite anatomy,

* W. D. Matthew.—On Antennæ and other appendages of Triarthrus Beckii. N. Y. Academy of Sciences, May, 1893; American Journal of Science, August, 1893.

C. D. Walcott.—Note on some Appendages of the Trilobites. Proc. Biol. Soc., Washington, March, 1894.

C. E. Beecher.—On the Thoracic Legs of Triarthrus. American Journal of Science, December, 1893.

————On the mode of Occurrence, and the Structure and Development of Triarthrus Becki. AMERICAN GEOLOGIST, January, 1894.

————The Appendages of the Pygidium of Triarthrus. American Journal of Science, April, 1894.

since from the beginning of these investigations it has not been possible to predict with safety the exact form and details of any of the appendages. Even their presence has been more or less doubtful until revealed by a fortunate discovery.

The paired appendages of the cephalon will be taken up in their order, beginning with the most anterior, next the newly observed characters of thoracic legs; then the organs in the median line, the hypostoma, mouth, metastoma and anal openings.

Close observation of the specimens thus far prepared for the purpose of showing the under side of the head fails to detect more than five pairs of appendages attached to the cephalon, apparently corresponding to the five typical limbs of the crustacean head. Considerable difficulty is experienced in determining from the ventral side of the specimens the posterior limit of the cephalon. The ventral membrane, which alone is usually visible, does not show marked evidence of segmentation, and the observer is guided chiefly by the margin of the cephalon, the extremities of the pleura, and obscure transverse lines on the axial membrane. In a few cases, the evident sliding or displacement of the dorsal and ventral surfaces further complicates the attempt to refer the appendages to definite divisions of the animal.

Paired uniramose appendages.

Anterior antennæ, or antennules. These have been described by Matthew, Walcott and the writer (l. c.). Walcott showed their proximal extremities and their mode of attachment at the side of the hypostoma. Little more can now be added except that they are evidently the first pair of antennal organs, and correspond to the antennules of other Crustacea. The strong basal joint or shaft is shown in plate v, figures 9, 10, 11, attached to the ventral side of the head at each side of the hypostoma, near the middle of its length. The shaft carries a single flagellum, and thus agrees with the typical uniramose antennule of the nauplius of Crustacea. This simple antennule is still present in the Isopoda, as in *Munnopsis typica*. The flagella curve forward and approach, nearly touching as they cross the doublure. Beyond the limits of the head, they are variously disposed, though usually extend-

ing forward. at first diverging for half their length and then slightly converging (plate v, figures 5, 6, 7).

Paired biramous appendages.

The remaining paired appendages of the trilobite all seem to be biramous, and agree closely in their general features. Adjacent members of the series present very slight differences. It is only when the primitive and simple phyllopodous legs of the pygidium are compared with the anterior thoracic or cephalic appendages that variations of note can be observed, although these are of form and not of structure. On this account, there is no well-defined separation into posterior antennæ, mandibles, maxillæ, maxillipeds, thoracic, and pleopodal appendages. It is most convenient, therefore, to number them from before backwards, and to indicate homologous positions with other Crustacea only when there is some evident reason for so doing.

First pair of biramous appendages, or posterior antennæ. The second pair of appendages, corresponding to the posterior antennæ, are attached to the head at each side of the glabella, on a line with the extremity of the hypostoma. They are apparently biramous, and thus agree with the second pair of nauplian limbs and with the typical posterior antennæ of many Entomostraca and Malacostraca. They may be compared with the posterior antennæ in *Euphausia pellucida*, one of the schizopods, especially with the *Furcilia* and *Cyrtopia* stages. The details of the endopodite and expodite are not clearly shown. The former is more commonly preserved, and its distal joint extends just beyond the edge of the carapace. The coxopodite is developed into a triangular plate, the inner angle carrying a masticatory ridge, the whole extending about three-fourths the distance from the side of the glabella to the median line, just below the hypostoma, and directed obliquely backwards (plate v. figures 8-11).

Second pair of biramous appendages, or mandibles. The appendages here correlated with the mandibles are immediately behind the first pair of biramous limbs. The proximal portion, or coxopodite, is similar in form to the preceding, though somewhat smaller, and overlapping its basal part. The palps, or endopodial and exopodial branches, have not been

distinctly traced, though their presence is indicated on plate IV, figure 1, where, on the left side, there are endopodites and exopodites in sufficient number for each appendage of the head. That these should be referred to the cephalic limbs is further indicated by their being in advance of the endopodite, which manifestly pertains to the first thoracic segment. The inner edge of the mandibles as well as that of the other gnathobases of the head is apparently finely denticulate, as shown on plate IV, figure 1, and plate V, figure 2.

Third and fourth biramous appendages, or maxillæ. Following the appendages referred to the mandibles are two pairs of strong limbs, with broad plate-like basal portions, or coxopodites, serving as gnathites (plate V, figures 8-11). They resemble each other, and are similar in form to the two preceding limbs, though somewhat larger. They are usually fairly well preserved and their form and structure can be approximately made out. The endopodites are composed of stout joints, and could be extended but a short distance beyond the margin of the head. The exopodites are more slender and carry an abundance of stiff setæ, which often diverge in a fan-like manner from their line of attachment. These brushes of setæ occupying the cavities of the cheeks are often preserved in specimens where the other details of the limbs are obscure or obliterated. In *Triarthrus* they are evidently homologous with similar brushes observed by Walcott in *Calymene*.*

This completes the number of paired appendages which can be definitely referred to the head. It is evident they do not differ conspicuously from each other, and, as will be presently shown, they closely resemble the thoracic legs in all essential structural characters.

Thoracic legs. In the paper by the writer (l. c.) describing the structure of the thoracic legs, the endopodites and exopodites of the second and third pairs were illustrated, together with their points of attachment. The form of the coxopodite, or basal portion, was at that time unknown. With the present material it is possible to add several details. The most important are the inward prolongation of the coxopodite of each

*The Trilobite: New and Old Evidence relating to its Organization. Bull. Mus. Comp. Zool., vol. VIII, No. 10, 1881.

limb towards the axial line, forming a gnathobase, and the progressive development of this member. First it has a slender cylindrical form in the posterior half of the series, then becomes flattened and denticulate, and finally widens, until on the head it forms the triangular plate-like coxopodite, with masticatory ridge and functioning as a gnathite (plate IV, figure 1; plate V, figures 1-4, 8-11).

The large basal portions of the limbs of *Asaphus*, in the specimen illustrated by Walcott (Science, March, 1884), are evidently the gnathobases, as will be seen at once from a comparison with *Triarthrus* (plate IV, figure 1).

Organs in the median line.

The hypostoma. There is nothing peculiar in the hypostoma of *Triarthrus*, since it presents features commonly found in many other genera. It is longer than wide, and extends more than half the length of the head. The posterior end is narrowly rounded, margined by a slight doublure, and often presents a transverse elevation near the apex, as shown on plate V, figure 9. This may represent a corresponding hollow on the inner side to allow for movements of the manducatory organs.

In considering the exact location of the appendages of the head, it must be understood that in their present positions they are probably somewhat displaced. During the process of fossilization the whole inner tissues of the animal were removed without replacement, allowing the ventral membrane to come more or less in contact with the under side of the dorsal crust, and thus causing some stretching of the membrane and consequent displacement of the organs. The hypostoma, being more rigid and attached in front to the margin of the head, doubtless was not shifted but dropped down into the cavity of the glabella. When raised to its natural position it probably extended a little over the mouth parts. The fact that the mouth and lower lip do not come opposite the organs correlated as mandibles may be due in part to the unequal stretching of the membrane over the uneven inner surface of the dorsal crust. The extended gnathobases directed obliquely backward and lying in the axial hollow cause the appendages to appear as though originating further back than is really the case. Nevertheless, the posterior position of the

second and third pairs of appendages, or the antennæ and mandibles, with respect to the mouth, does not offer any serious difficulty. As shown by Lankester,* they were doubtless originally post-oral in the Crustacea, as is indicated from their innervation from the ventral nerve ganglion chain and not from the archicerebrum of the prostomium, or cephalic lobe. Besides, in the embryo of *Limulus* all the appendages are post-oral, as shown by Packard.†

The mouth. Although the opening of the mouth itself has not been observed in *Triarthrus*, there can be little doubt as to its exact location, since it must have been situated in the median line between the hypostoma and metastoma. As both these organs are quite close together, the place of the mouth would be as indicated on plate v, figure 11 *m*. Further corroborative evidence may be had from the genus *Calymene*, in which the mouth was determined by Walcott (l. c.) to lie at the end of the hypostoma, opening obliquely backward.

The metastoma. The lower lip, or metastoma, here represented for the first time, is generally clearly shown as a convex arcuate plate just posterior to the extremity of the hypostoma. On each side, at the angles, are two small elevations, or lappets, which suggest similar structures in many higher Crustacea, and apparently represent the entire metastoma in *Apus* and some other forms (plate v, figures 9, and 11 *met*).

The anal opening. In tracing the intestinal canal as preserved in *Trinucleus*, Barrande determined its posterior termination to be at the extremity of the pygidium, and Bernard‡ has recently succeeded in reaching a similar conclusion, from his studies of *Calymene*, in which the anal opening was found just at the inner margin of the doublure of the pygidium, in the median line. Plate iv, figure 1, of *Triarthrus*, shows the anus in the same position, outlined by a slightly elevated wrinkled ring.

Observations.

With these additional discoveries relating to *Triarthrus*,

*Observations and Reflections on the Appendages and on the Nervous System of Apus cancriformis. Quar. Jour. Mic. Sci., vol. xxi, 1881.

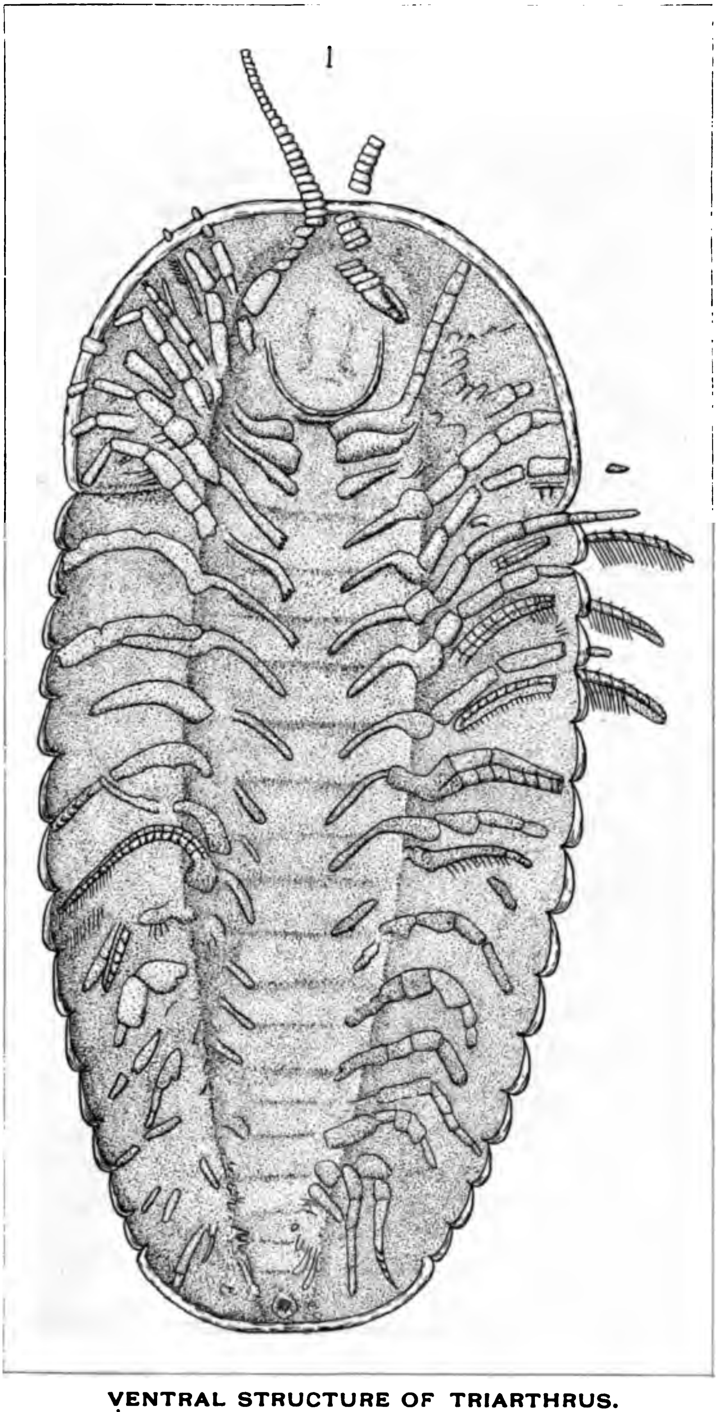
†The Development of Limulus polyphemus. Mem. Boston Soc. Nat. Hist., vol. ii, 1872.

‡The Systematic Position of the Trilobites. Quar. Jour. Geol. Soc., vol. l, 1894.

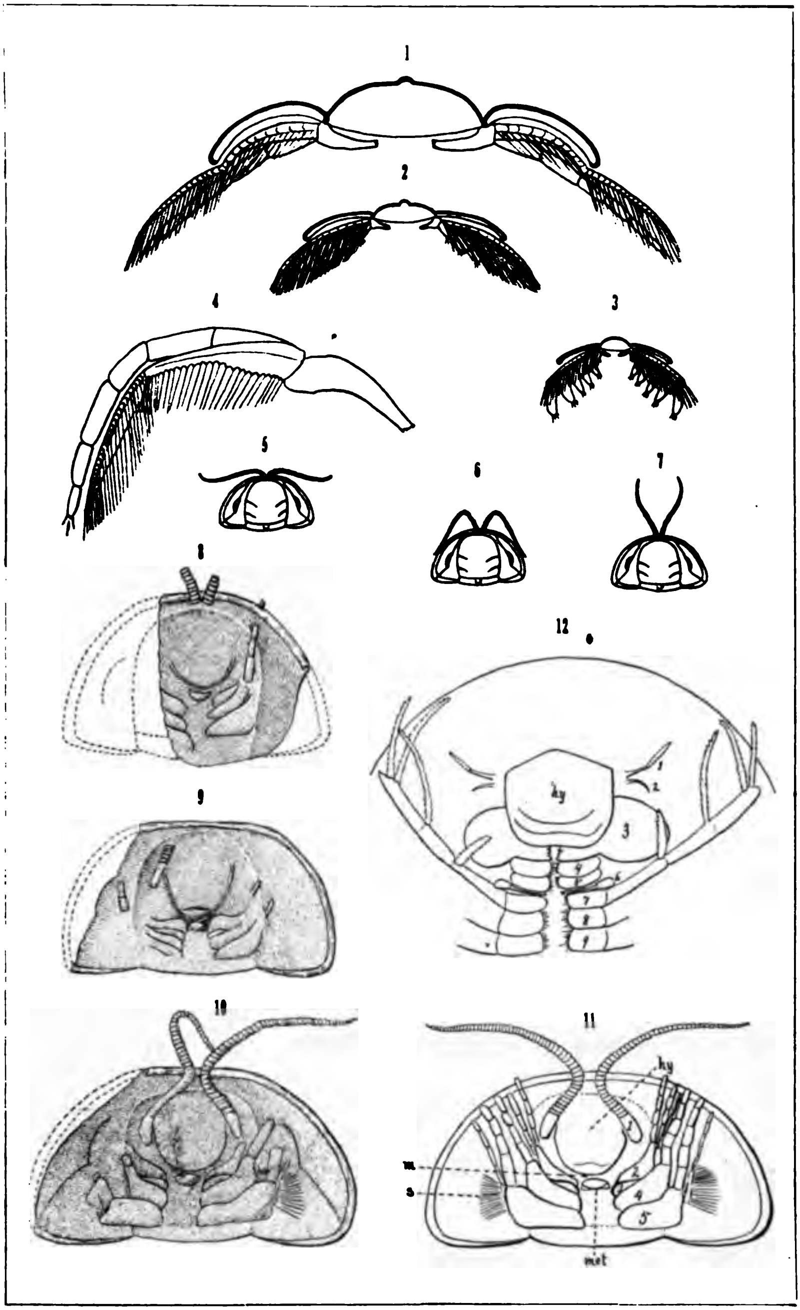
several observations upon its general organization and comparisons with other Crustacea may be made. This cannot be done exhaustively or comprehensively at this time, and only a few points will be touched upon. The simplicity and primitiveness of the trilobite structure will first impress the student. The variable number of segments in the thorax and pygidium in the different genera shows the unstable metameric condition of the class. The head alone seems to have a permanent number of segments and appendages. Even this is not often apparent, but the constant number of five head segments in larval trilobites shows this to be the true number, although subsequent growth may obscure or obliterate this pentasomitic character, as has been shown by the writer in *Acidaspis* (Am. Jour. Sci., Aug., 1893) and observed in other genera.

With the exception of the antennules, all other paired appendages of the animal seem to agree in every point of structure, and vary only in the relative development of certain parts. The appendages of the pygidium are ontogenetically the youngest, and express the typical phyllopodiform structure. Passing anteriorly, the joints become less leaf-like, until in the anterior thoracic legs they are quite slender, and the limbs resemble those of schizopods. Corresponding to this, there is, through the whole series, a gradual development of a process from the coxopodite, forming a gnathobase to the limb. On the head, these serve as true manducatory organs. Posteriorly, they were like the basal endites of *Apus*, and enabled the trilobite to convey food along the entire length of the axis to the mouth.

Bernard (l. c.) has made a strong exposition of the evidence in favor of the phyllopod affinities of the Trilobita, and especially of their relations to *Apus*. A portion of the under side of the head of *Apus* is introdueed for comparison on plate v, figure 12. Both pairs of antennal organs (1, 2) are rather rudimentary in this genus, and are situated further forward than in *Triarthrus*. The powerful mandibles (3) are partly covered by the labrum, or hypostoma (*hy*). Then follow two well-developed gnathobases, representing the maxillæ (4, 5), the more slender maxilliped (6) and the large first thoracic limbs (7), behind which are the basal endites, or gnathobases, of two of the phyllopo-



VENTRAL STRUCTURE OF TRIARTHRUS.



VENTRAL STRUCTURE OF TRIARTHRUS.

dous appendages (8, 9). The general similarity of the cephalic organs of *Apus* and *Triarthrus* is quite apparent. The most conspicuous differences, as the absence of normal endopodial and exopodial elements, disappear in a study of the ontogeny of the limbs of *Apus*, thus bringing these organs in the two groups into nearly exact correlation.

There are, however, important structural features of other parts of the body, which are quite dissimilar from *Apus* and the higher Crustacea, and the exact relations of the trilobite with any one group cannot be considered as fixed. Points of likeness may be established with almost every order, showing chiefly the relationship between the trilobite and the ancestors of modern Crustacea.

Summary of ventral organs of Triarthrus.

A pair of appendages to each potential segment of the animal, all of which are biramous except the anterior pair.

Five pairs of appendages on the cephalon.

Anterior antennæ, or antennules, attached at the sides of the hypostoma; simple, with a single many-jointed flagellum.

First pair of biramous limbs, or posterior antennæ, with endopodite and exopodite; basal portion manducatory in function.

Second pair of biramous limbs, or mandibles, similar to preceding.

Third and fourth pairs of biramous limbs, or maxillæ, same as preceding, with large gnathobases, well-developed endopodites and fringed exopodites.

Thoracic limbs biramous; endopodite a jointed crawling leg; posteriorly the joints become flattened and leaf-like; exopodite fringed with setæ, and developed into a swimming organ; coxopodite with gnathobase.

Appendages of the pygidium, true phyllopodous limbs.

Hypostoma.

Mouth between hypostoma and metastoma.

Metastoma, a convex crescentic plate, with side lappets.

Anus in median line, near ventral extremity of pygidium.

EXPLANATION OF PLATES.

PLATE IV.

TRIARTHRUS BECKI Green.

Figure 1.—Ventral side of a large specimen; showing at each side of the hypostoma the antennules, with their single flagellum and strong

basal joint; also the biramous cephalic appendages, with large gnathobases; the biramous thoracic limbs, with gnathobases extending obliquely backward in the axis of the trilobite; and the hypostoma, metastoma, and anus, in the median line. ×4. *Utica slate*, near Rome, N. Y.

PLATE V.

TRIARTHRUS BECKI Green.

Figure 1.—Diagrammatic restoration of second thoracic limb in transverse section of trilobite; showing gnathobases extending under the axis toward the median line, and the biramous limbs under the pleura and beyond the carapace.

Figure 2.—Diagrammatic restoration of anterior pair of pygidial limbs: showing phyllopodiform structure.

Figure 3.—Diagrammatic restoration of posterior pair of pygidial limbs; showing more strongly the primitive phyllopodous structure.

Figure 4.—Dorsal view of second thoracic leg, with gnathobase. ×12.

Figures 5, 6, 7.—Dorsal views of three heads; showing antennules. Their position in figure 7 is the most common.

Figure 8.—Portion of under side of head; showing platelike gnathobases of cephalic limbs, posterior part of hypostoma, the metastoma, and one endopodite on the right. ×4.

Figure 9.—Under side of head with gnathobases and metastoma better preserved. ×4.

Figure 10.—Under side of head; showing antennules and their points of attachment, the four pairs of gnathobases of the other cephalic limbs, and the hypostoma and metastoma in the median line. ×4.

Figure 11.—Diagram; showing the cephalic appendages preserved in figures 5, 6, 7, and figure 1, plate IV. 1, shaft of antennule bearing a single flagellum; 2, coxopodite of first pair of biramous limbs, or posterior antennæ; 3, third pair of cephalic limbs, or mandibles; 4, 5, gnathobases of fourth and fifth pairs of cephalic limbs, or maxillæ; *hy*, hypostoma; *m*, mouth; *met*, metastoma; *s*, setæ. This figure is not intended as a complete restoration of the cephalic appendages, but only as a diagram for convenient reference, combining the characters preserved in the specimens illustrated.

Figure 12.—Portion of the under side of the head and thorax of *Apus*; *hy*, hypostoma; 1, antennule; 2, posterior antenna; 3, mandibles; 4, 5, maxillæ; 6, maxilliped; 7, first thoracic leg; 8, 9, basal endites of phyllopodiform legs. ×3.

THE SECOND LAKE ALGONQUIN.

By FRANK BURSLEY TAYLOR, Fort Wayne, Ind.

(PLATE VI.)

INTRODUCTION.

One of the results of recent explorations of the upper great lakes has been the finding of conclusive proof that their

basins were lately occupied by an extensive lake, which had its outlet eastward across the Nipissing pass at North Bay, Ontario. This extinct lake comprised all three of the present upper lakes, but its area was not much greater than their present combined areas. Its waves made a heavy and unmistakable mark along its shores, and this abandoned beach may be easily distinguished from all others and traced continuously. No other beach of that region has such a clear and strong character and none is so easy of access and identification. Its place shows that the water stood about 45 feet higher than lake Huron stands now in the straits of Mackinac and 50 feet above the level of lake Superior at Sault Ste. Marie. The connection of that time between lakes Superior and Huron was a narrow strait, probably with a sluggish current, but certainly with no "sault" or rapids like those of the present river. Since the time of this lake the lands which formed its shores have been slightly tilted upward toward the north-northeast, and its southwestern shores are submerged beneath the present waters of the lakes. As we shall see presently, this extinct lake is destined to hold an important place in recent geological history. For it marks a transition stage between the present order of things and a time when the salt water of the ocean came into the great lakes through a strait over lake Nipissing, 25 miles wide and 500 feet deep. Dr. J. W. Spencer has already described a postglacial lake which occupied the same basins, but his conception of its age, epochs and stages is not the same as is here set forth. He called it lake Algonquin. Following his usages as closely as possible, I adopt this name for the lake described below. While it differs in some important respects from Dr. Spencer's lake Algonquin, the abandoned beaches of the two being entirely independent throughout, its outlets were the same and it will probably be found in the end that this lake was only a second or later epoch of the same lake which he described.* Lake Algon-

*"Notes on the Origin and History of the Great Lakes of North America," by J. W. Spencer, Proc. A. A. A. S., vol. XXXVII, 1888. In the note at the bottom of page 199 definitions are given for the ancient "Laurentian" and "Erigan" rivers, and also for lakes "Algonquin" and "Iroquois." Lake Algonquin is defined as the ancient "Huron-Michigan-Superior lake." The name "Algonquin" is applied also to "the beach which marked its [lake Algonquin's] shores, and the river which discharged its waters by the Trent valley." Beginning on the preceding

quin as described in this article is defined as a postglacial lake, now extinct, but which recently (since the marine invasion) had its outlet eastward across the Nipissing pass at North Bay, in the province of Ontario.

The great abandoned shore line which marks the highest level of lake Algonquin as just defined is known as the Nipissing beach, and its extension westward from North Bay along the north coast of lake Huron and the south coast of lake Superior to Duluth has been described by the writer in other articles. It is the object of the present paper, after first tracing the identity of the Nipissing beach to points farther south, to sum up our present knowledge of the whole extent of lake Algonquin and to tell as much as is now known of the history of its subsequent deformation. Most of the facts referred to are contained in the following series of descriptive articles, which are given below in the order of their publication and will be referred to hereafter by number. The maps which accompany these papers show the details described much better than the one which illustrates this article.*

---

page is an account of the dismemberment of "lake Warren" and of the formation of lake Algonquin with its Trent valley outlet. Evidently Dr. Spencer did not know at that time of the abandoned river outlet at the Nipissing pass, northeast of Georgian bay. But he has since recognized this fact. When we come to discuss in another paper the relations of the higher shore lines of the upper lakes it will be shown that lake Algonquin has probably had two distinct and separate epochs of existence, both in postglacial time, and the Algonquin beach, extending from near Port Huron to a point north of Kirkfield, Ontario, where Dr. Spencer's tracing ceased, is probably merely a deformed or elevated shore-line of the first epoch of the lake's existence. There is considerable evidence to support this view. The lake described in this paper is then in reality the *second* lake Algonquin. If the Algonquin beach is not the shore of a first lake Algonquin, then it is merely a much deformed extension of the Iroquois beach

In conversation, Dr. Spencer informed the writer lately that the supposed Trent valley outlet had been found to be obstructed below the place of his previous observations and had probably not been an outlet at all. The two epochs of lake Algonquin's existence were separated by a long period of time during which the sea entered the basin of the upper lakes through the ancient Nipissing strait. During this interval great uplifts took place and produced large deformations of the marine shores and also of the shores of the first lake Algonquin. But all this precedes the time of the events discussed in this paper, and inasmuch as the first epoch of the lake's existence has not yet been discussed, it is not deemed necessary to use the phrase "second lake Algonquin" throughout this article.

*All these papers except the first and sixth were published while I was absent in Europe, so that I had no chance to see the proofs. Con-

(1). "The Highest Old Shore Line on Mackinac Island." Amer. Jour. Sci., 3d Ser., vol. XLIII, March. 1892.
(2). "The Ancient Strait at Nipissing." Bull. G. S. A., vol. v, 1893.
(3). "A Reconnaissance of the Abandoned Shore lines of Green Bay." AM. GEOLOGIST, vol. XIII, No. 5, May, 1894.
(4). "A Reconnaissance of the Abandoned Shore lines of the South Coast of lake Superior." AM. GEOLOGIST, vol. XIII, No. 6, June, 1894.
(5). "The limit of Postglacial Submergence in the Highlands East of Georgian Bay." AM. GEOLOGIST, vol. XIV, No. 5, Nov., 1894.
(6). "The Munuscong Islands." AM. GEOLOGIST, vol. XV, No. 1, Jan., 1895.

Facts relating to the Nipissing beach are scattered through all these papers, but the principal number are contained in the second, fourth, and sixth.

THE SOUTHWARD EXTENSION OF THE NIPISSING BEACH.

On the Northern Shores. In the second of the preceding papers an account is given of the Nipissing beach at North Bay, and it is there shown that its relation to the ancient pass eastward to the Ottawa valley agrees perfectly with the supposition that the great lakes had a postglacial outlet in that direction. The probable existence of this outlet had been previously suggested by Gilbert,* and Spencer; and later observations by Gilbert,† Wright,‡ and the writer§ have substantially established the fact. Over the watershed east of North Bay this river had a width of a little over a mile, a maximum

---

sidering this fact the errors are few; but the following corrections should be made:—

Second paper, page 624, fifth line from bottom, for "more than 500 feet" read "nearly 500 feet." Next page, seventh line from top, for "Silver lake" read "Windy lake." In the description of the map on the same page lake Temiscamang should be marked "4" and lake Abitibi "8."

Third paper, table on page 325, the altitude of the beach southward of Two Rivers, Wis., for "582" read "—582."

Fourth paper, page 369, eighteenth line from bottom, for "the shore line," read "this shore line." Then two lines below, for "must be," read "might be;" and on page 375, fourth line from bottom, for "northeast" read "northwest."

Fifth paper, page 282, bottom line. For "station" read "sea;" page 289, first line of last paragraph, after "the" insert "higher."

*"The History of the Niagara River," by G. K. Gilbert in Annual Rept. of Com'rs of State Reserv. of Niagara, 1889. Also in Rept. Smithsonian Institution, 1890.

†See introduction to second paper of above list.

‡"The Supposed Postglacial Outlet of the Great Lakes through Lake Nipissing and the Mattawa River," by G. F. Wright, Bull. G. S. A., vol. IV, with Dr. Bell's remarks.

§Second paper of above list

depth of about 35 feet and an average depth of not more than 25 feet.* This seems to imply a larger volume than the present Niagara at Buffalo. But it is very probable that the narrow, rocky place ten miles east of the present divide, as mentioned by Mr. Gilbert,† was the original col, and that the volume of the river may be more truly measured by it.

In the fourth paper the Nipissing beach is described in its extension along the north shore of lake Huron and the south shore of lake Superior to Duluth, a distance of over 600 miles. Its development throughout is so characteristic that it is readily recognized wherever seen and is not liable to be confused with any other beach. Nearly all the points of identification in the north are close to a line connecting Duluth and North Bay. The widest departures are the localities on the Keneenaw peninsula. Probably Prof. Lawson could identify this beach at points still farther north.‡ But its extension in that direction is not a matter of such critical possibilities as it is towards the south; for the reason that the whole north side of lake Superior is a high coast which offers no chance for an outlet within the range of this beach. This is not the case, however, towards the south. The lands bordering that side of lakes Huron and Michigan are exceptionally low. The present outlet of the upper lakes is in that direction, and there is the abandoned Chicago outlet, which also lacks but little of being active at the present time.

Mackinac and the East Michigan Shore. Since the discovery of the Nipissing beach on the coasts of the north, a new significance has attached to certain beaches previously observed at other points farther south. In the first paper the

*Not a depth of "fifty feet upon a width of more than a mile," as Mr. Warren Upham puts it in his letter in the AMERICAN GEOLOGIST for July, 1894. From the crest of the divide down to Trout lake on the east there is a drop of about 25 feet. But the shore line along the north side of the old channel continues level, proving apparently that there was no steep descent of water across the divide. This strongly supports Mr. Gilbert's suggestion as mentioned in the second sentence below. (See introduction and first topic of the second paper.)

†Postscript to Mr. Upham's letter.

‡"Sketch of the Coastal Topography of the North Side of Lake Superior, etc.," by A. C. Lawson. Twentieth An. Rept. Minnesota Geol. and Nat. Hist. Survey, 1893. The bearing of Prof. Lawson's observations upon the place of this beach in the north will be briefly discussed in another paper entitled "The Nipissing Beach on the North Superior Shore."

exceptional strength of a beach at an altitude of about 45 feet on Mackinac island was briefly mentioned. It is the one upon which the higher parts of the village are built. It appears again in the ridge near British landing, as mentioned in the sixth paper; and it is continued in the great cut terrace which extends across the north end of the island.

Passing over to the north mainland, it is this same beach which displays the immense gravel beds so conspicuous at St. Ignace and all around the flanks of Gros Cap. It was the beach drift of this time that shut in the ponds and swamps northwest of St. Ignace, and formed Brevoort lake near the Michigan shore twelve miles northwest. This beach is also well developed along the shore northward from St. Ignace, and it was the wave-cutting of that time which made the steep precipice of St. Louis rock two miles north.

On the south side of Mackinac straits it appears again as the lower terrace at McGulpin's point. The light house is built upon it and it appears as a cut terrace at the foot of a steep bluff extending around the entire point to Cecile bay; and still farther to the long Waugoshance point, which is partly a spit of this age. Round island and Bois Blanc southeast of Mackinac rise only a little above it and their tops look as though they had been largely planed down to that level. The tops of the Cheneaux islands are apparently limited by the same plane.

Still farther south in the vicinity of Little Traverse bay this beach reäppears in magnificent form, mainly as a cut terrace. But its hight there is reduced to about 25 feet above the lake. It is upon this shelf that the villages of Harbor Springs and Wequetonsing are built. The bluff at its back is 75 feet high and very steep. The long spit which makes the beautiful little harbor there was probably begun at that time, although it has been largely extended since. Across the bay this beach appears at Petoskey as the lower terrace down near the lake, and again at Bay View in the same relation. In the eastern part of the latter village and beyond it becomes very wide with a high steep bluff at its back. But its strength of development becomes greatest at the head of the bay. The breadth between the higher lands at that place is upwards of two miles. The old channel through to the east was not deep,

but it has been filled in with gravel and sand for two or three miles. Much sand has been added to the top of the gravel in later times. Some of the modern dunes at the head of the bay are nearly 100 feet high, and there are old ones still higher, now covered with trees. About a mile east of the bay on the line of the railroad, there is a little shallow pond called Mud lake, which is about 20 or 25 feet above the bay. Its waters flow eastward into Round lake which is much larger, but still only a small lake. The water then flows into Crooked lake, then into Burt's lake, then into Mullet lake and finally through the Cheboygan river into lake Huron 18 miles southeast of Mackinac. The direction of at least the western part of this drainage system was determined by the littoral drift of the strong beach referred to. It is doubtful, however, whether this particular beach can be traced farther south on the facts at present in hand. Traverse City is built upon a flat which appears to be an old delta about ten feet above the lake. But this shelf is not certainly identified with the lower beach at Petoskey. Estimated from its plane at Petoskey, Mackinac and Sault Ste. Marie, the beach described should pass under the lake at a point ten or fifteen miles north of Traverse City.

Returning to the mainland north of Mackinac, we should expect to find this strong beach on the wide terrace north of Hessel. But the back of the first terrace against the foot of the first steep bluff is about 100 feet above the lake. This is considerably too high for identification with the beach of 45 feet at Mackinac. It seems probable, therefore, that this beach rests somewhere upon the surface of the long, sloping stony swamp described in the sixth paper. Although a beach of the same description has not yet been reported between Mackinac and St. Joseph and Sugar islands below Sault Ste. Marie, there can hardly be a doubt of its identity; it is a part of the Nipissing beach, and marks the shore of lake Algonquin. It lies in the same plane and shows the same deformations and has the characteristic strength of the Nipissing beach farther north. On every ground of comparison its identification is complete.

The West Michigan Shore. On the west side of lake Michigan the Nipissing beach was clearly identified, especially

around the northern shore of Green bay. But it was not found south of Escanaba. From Sault Ste. Marie to the vicinity of Old Munising, the Nipissing beach on the Superior shore declines about 25 feet. Supposing it to have the same declination on the south side of the peninsula, and starting at 45 feet at Mackinac, it ought to appear at the north end of Green bay at an altitude of about 20 feet, and there is a strong shore line there approximately at that hight. It is the wide flat upon which the higher parts of the towns of Gladstone and Escanaba are built. Back of the former place its upper mark is strong and plain against the foot of a high steep bluff. The bluff was described in the third paper of the above list, but by an oversight the lower wide terrace at its foot was not mentioned. It was at this time also that the spit at Fayette on the Garden peninsula was made. The heavy beach gravels of the low Nahma peninsula opposite Gladstone probably belong to the same time. The upper beach, which is also a strong one, descends gradually southward on both sides of lake Michigan and lies only 50 to 75 feet above the Nipissing beach where the latter was last seen toward the south. The declivity of the upper beach grows less toward the south and it there forms a plane nearly parallel with that of the Nipissing. Possibly the earlier observations of Dr. Andrews and Mr. Bannister carry the identity of some of these beaches farther south. But although I have not yet seen their papers, it seems improbable that such is the case. For, as is stated in the third paper, the upper beach passes under lake Michigan on the west side at Two Rivers. On the east side it is estimated to pass under the lake at a point about 60 or 70 miles south of Traverse City, probably near Ludington or Pentwater. The higher beaches described by these observers and by Mr. Leverett* at points farther south, certainly have no extension in the north. They are probably fragmentary and mark the shores of a lake of the glacial recession which had its outlet at Chicago. It is estimated that the Nipissing beach passes under the present lake at points about 30 miles north of Menominee and 15 miles north of Traverse City. Neither the Nipissing nor the upper

*"Raised Beaches of Lake Michigan," by Frank Leverett. Wisconsin Acad. Sci. Trans., vol. 7, p. 177-192, 1889.

beach, therefore, has any connection with the Chicago outlet unless they change the attitude of their planes southward in a very exceptional manner. The nodal points of both beaches are a little farther south on the east side of the lake than on the west. But if the Nipissing beach extends as far south as Chicago in the same plane it passes 120 to 130 feet below the present lake level at that place, and the upper beach with a slightly steeper descent probably strikes nearly as deep.

The West Huron Shore. So far as relates to postglacial submergence the eastern coast of Michigan from Cheboygan nearly to Port Huron is almost a *terra incognita.* Dr. Spencer has located the Algonquin beach along that shore conjecturally, and he is probably correct in making it pass under the water of Saginaw bay.* But this beach, even where lowest towards the south, has always been found to be at least a few feet above the Nipissing beach. As a boy the writer remembers very well seeing the great sand spit which forms the east shore of Thunder bay at Alpena, and also the sandy road along the shore westward. Presque Isle and the numerous littoral lakes of that coast strongly suggest similar shores elsewhere which owe their modification to the Nipissing beach. But this is all that can be said of this coast at present.

The East Huron Shore. As to the east side of lake Huron, the facts at hand are almost as meager. At North Bay the Nipissing beach is about 160 feet above the lake. At Parry Sound it is very doubtful whether the small gravel delta at about 50 feet in the village is the Nipissing beach. At Midland there is a strong sandy terrace at about 50 feet. It is the lowest and much the strongest of the series near the lake shore, as described in the fifth paper, and it was easily followed about four miles westward around the head of the bay. This shore line compares very favorably with the Nipissing beach as seen elsewhere. But it is the only locality on this coast south of North Bay where I have had a good chance to see Nipissing beach. In this region, however, my work overlaps that of Dr. Spencer, who has described the abandoned beaches of the south coast of Georgian bay and the east coast

*"Deformation of the Algonquin Beach and Birth of Lake Huron," by J. W. Spencer. Am. Jour. Sci, vol. XLI, Jan., 1891.

of lake Huron in considerable detail.* He describes a beach which descends westward along the south side of Georgian bay and southward along the east shore of lake Huron. Towards the south its declivity decreases and he estimates that it passes under lake Huron to a depth of about 20 feet off Sarnia. Dr. Spencer has traced this beach to Kirkfield, north-east of lake Simcoe in Ontario, and I have found it at intervals as far north as North Bay, and at high altitudes, as is recorded in the fifth paper. Dr. Spencer calls the whole extent of this shore line the Algonquin beach, and considers it to be one continuous feature and of the same age throughout. Apparently he takes no account of the possibility that, in the varying vicissitudes of the lakes, beaches of different ages might have overlapped. Yet he finds the Algonquin beach passing under the present level of lake Huron, suggesting clearly that similar relations may have obtained between other beaches in the past. Indeed, it seems probable that the Algonquin beach is divisible in this way at some point between lake Sincoe and North Bay, into two parts of different ages. If the plane of the Nipissing beach as it is on the south coast of lake Superior and the northern part of lakes Michigan and Huron be projected toward the southeast, it passes about 25 feet under lake Huron at Sarnia and thus comes into very close agreement with the southern end of the Algonquin beach; and it also strikes very close to the level of the heavy sandy beach of 50 feet at Midland on Georgian bay. The probable identity of the low-level shore lines of this region with the Nipissing beach is further supported by Dr. Spencer's description of their character. He says the country around the head of Georgian bay is sandy. The Nipissing beach is notably so in many places. He says that along the eastern coast of lake Huron the waves are now cutting away the land and have in many places removed the bluffs on which the Algonquin beach rests.† This same cut would remove anything that might have remained of the Nipissing beach also. Dr. Spencer states that the mean rate of rise of the Algonquin beach from the southern end of lake Huron to near Southamp-

*See last reference above.

†"Deformation of the Algonquin beach," etc.,(referred to above,) page 13.

ton is 1.33 feet per mile. This rate decreases toward the south and increases toward the north. Speaking of the Algonquin beach along this shore he says that it is "often broken up into a series of prominent ridgelets, the lowest being, where developed, as much as 28 feet below the upper."* This is a very marked feature of the Nipissing beach in many places.

Concerning the beaches of the south coast of Georgian bay, Dr. Spencer says: "There are several beaches about Georgian bay, at lower altitudes than the Algonquin, but these rise less rapidly toward the northeast than the greater named beach. At Clarksburg there is a beach at 81 feet above the lake, and terraces at 62 and 45 feet, besides a numerous series of beaches extending from 28 feet down to the water level. Near Wyebridge, the more conspicuous terraces are at about 183, 73, 55 and 11 feet above the lake; and there are numerous fainter shore lines." Wyebridge is only about nine miles south of Midland, and it seems more than probable that the beach of 55 feet at the former place is the same as that of 50 feet which I observed at the latter, and that there is some discrepance in my measurement. Clarksburg is about 30 miles southwest of Midland and the Nipissing beach should be expected there 10 or 15 feet lower. Dr. Spencer's beach at 45 feet at that place seems to fit the case very closely, and the numerous beaches below 28 feet add still more of the Nipissing quality. It is further notable that this "numerous series" keeps to a low level, as would be expected if it were of Nipissing age. In short, so far as the evidence goes, it shows that the Nipissing beach is in its normal place on these shores and lies about in the same plane as those parts of it which have been traced on shores 200 to 500 miles to the northwest. If these points of identification are correct, then the Nipissing beach should be about 35 feet above lake Huron at Southampton, and should pass under the lake at a point about 10 miles south of Goderich. Thus at all points above the lake level the Nipissing beach is below the Algonquin, although it is estimated to strike almost exactly at the same level under the lake off Sarnia. The higher, steeper Algonquin beach which rises more

*Op. cit., p. 16. Next quotation from same page also.

rapidly to the northeast is, therefore, a thing of different age.*

In the case of the Nipissing beach the value of the supposition of its extension, as above, to the southern shore of lake Huron is strengthened by the fact that although it has been traced to widely separated points elsewhere, this beach is not known to depart suddenly or greatly from its mean plane. The only notable exception to this statement is the accelerated rise northeastward toward the North Bay outlet in the region northeast of lake Huron. But at North Bay the altitude of the beach above the main plane produced to that place from the west is only about 40 feet.

THE CHANGE OF THE OUTLET AND THE DEFORMATION OF THE NIPISSING PLANE.

Theoretical Considerations. We have now before us a résumé of the principal facts relating to the Nipissing beach of lake Algonquin so far as at present known, and upon these as a basis we must endeavor to learn what we can of the history of that lake and the proximate causes of the changes which led to its deformation. But first a brief consideration of certain theoretical principles will help us to understand the nature of the changes which have taken place.

If a basin which receives a continuous supply of water and maintains a continuous outflow be tilted in any direction, its relation to the plane of the water surface will be changed. If the outlet were on the east side and the basin were tilted up at that side, all the previous shores in the basin would be submerged. On the other hand, if the west side were elevated the previous shores would all be left dry. If the basin were tilted up at its south side only, the water would change its level on an axis running west from the outlet and all previous shores south of that line would be left dry, while all north of it would be submerged. On the other hand, if the north side were elevated the new relations would be just the reverse; previous northern shores would be left dry and southern ones

* In some of his recent papers Mr. Warren Upham has endeavored to show that the Nipissing beach is the same as Dr. Spencer's Algonquin beach. (See pp. 21-27, Bull. G. S. A., Vol. VI, 1894; pp. 57-66, Geol. and Nat. Hist. Survey of Minn., Part III, 1894; and Am. Jour. Sci., Vol. XLIX, Jan. 1895.) I have observed both beaches at the same locality. The two are entirely distinct and independent, the Algonquin always occurring above the Nipissing so far as yet seen.

would be submerged. These principles are very simple, and it is clear enough that if from any cause the attitude of the water instead of the land itself were made to change, the results produced would be the same. Supposing the basin to have two low places or possible outlets on its eastern rim, the results of tilting would be the same as before for east-west changes, but very different for those in a north-south direction. Let us suppose to begin with that the outflow is all by the northern outlet and that the southern one is dry. If the basin were slowly tilted up at its north side the water plane would swing at first on an axis passing west from the northern outlet. Northern shores would be left higher and higher as the movement progressed and southern ones would be submerged more and more deeply. The water at the south would therefore appear to rise upon the land; and, if the same change were continued, it would eventually rise to the level of the southern outlet. A further tilt would spill some of the water over the southern outlet and to that extent reduce the outflow by the northern one. Still another tilt, and the whole outflow would be shifted to the southern outlet and leave the northern one dry. Along with such changes as these, there might be others in an east-west direction. They would affect the position of the beaches, but not the relation of the outlets on the eastern rim, unless these were affected by different amounts.

A study of this kind reveals perfectly the larger factors in the history of lake Algonquin. Until the last hour of its existence lake Algonquin outflowed by the Nipissing pass. But progressive upward tilting at the north soon brought the St. Clair outlet into activity and ultimately gave it the whole discharge, leaving the Nipissing outlet dry. Subsequently, a continuance of the same order of change, followed by a large eastern uplift, has carried the northern outlet up to 160 feet above the present level of lake Huron, and brought the water up to within eight or ten feet of the Chicago outlet, whereas, in the time of lake Algonquin, the latter outlet was more than 100 feet above the lake.

In the foregoing discussion the basin of the lakes is supposed in each case to be tilted as a whole, as though it were a rigid vessel uplifted at one side. But in the course of time

irregular, local changes of more or less importance are almost certain to take place everywhere. With a single exception already pointed out, however, the attitude of the Nipissing plane shows the change to have been of the broader kind, affecting the whole basin as a unit.

In considering the process of the change of outlet, it is important to see that unless the movement which produced that change was extremely sudden (and there is no reason to suppose that it was), the outflow by the new outlet must have begun before the old one was abandoned. Dr. Spencer has said that the outlet could not have been southward by way of the St. Clair river at the time of the Algonquin beach.* But if we consider the case from the standpoint of the Nipissing beach, which is more nearly horizontal, the difficulties of such a supposition are greatly decreased. Indeed in this case such a conclusion is clearly disproved by a very simple consideration. In the tilting of a basin which has two possible outlets on its eastern rim, the uplift being at the north, it is clear that the highest shore line which can possibly be made between these outlets is in a plane which connects them when both are flowing. A change from this position either way would throw the whole discharge to one outlet and leave the other dry. It is therefore plain that the submerged beach off Sarnia marks the level of lake Algonquin at a time when the St. Clair outlet had just been fully established and the Nipissing outlet just abandoned. And there are no obstructions in the St. Clair or Detroit rivers which preclude the supposition that they might have been this much lower at that time. That this is not mere speculation is plain when we consider that some other outlet must have become active when that at North Bay went dry. But there is no other outlet available except that at Port Huron. After this one, the only other which might have been available is at Chicago. But the attitude of the Nipissing plane excludes that alternative absolutely.

Extension of the Nipissing Plane to Buffalo. The cessation of the North Bay outlet and the complete establishment of that at Port Huron marked the extinction of lake Algonquin and the beginning of the present order of things. Since

*Op. cit., p. 18. Also letter in AMERICAN GEOLOGIST for August, 1894.

that time the outflow by the St. Clair river has probably never been interrupted, and from this fact there follows an important conclusion. At the present time lake Erie is nearly nine feet below lake Huron.* It follows that at about nine feet above the water to the head of the Niagara river at Buffalo there is a point in the air which is now exactly in the plane of lake Huron. And since the outflow of the upper lakes has been through Niagara ever since the establishment of the St. Clair outlet, it follows further that this same point must have been at all times very nearly in the plane of lake Huron, departing from it only so far as the fall from lake Huron to lake Erie may have changed, or the Niagara river lowered its level at its head by erosion. As we shall see later, it is certain that the fall from Huron to Erie was a little greater at first than now. But both these factors together are evidently small, probably not exceeding 10 or 12 feet at most, making the fall at that time about 20 feet. The relation of the plane of lake Huron to the head of Niagara river must have been very nearly the same all the time. It follows that at the last hour of lake Algonquin this point nine feet above the river at Buffalo was only 10 or 12 feet below the plane of the Nipissing beach. For this reason then, that plane is extended by inference to Buffalo, and that place becomes the hinge upon which all the subsequent eastward elements of deformation turn. But Buffalo is almost exactly east of Port Huron so that the whole relative change between them has been an eastward component. Relative eastward elevation has taken place, probably amounting to 35 feet at Buffalo. This would be enough to drown the Nipissing beach about 25 feet at Port Huron; and the St. Clair and Detroit rivers were also similarly affected. Since this has taken place, Buffalo has become virtually the hinge of the northward component of deformation also. The truth of this is evident when we consider that the present level of lake Huron is to a considerable extent dependent upon the level of lake Erie. If Erie were to run dry, the level of Huron would speedily be lowered by several feet, presumably by 25 feet or to the former level of the St. Clair outlet. Buffalo is nearly straight south of North Bay so that

*"Physical Characteristics of the Northern and Northwestern Lakes," L. Y. Schermerhorn, C. E., Am. Jour. Sci., III, vol. XXXIII, April, 1887.

between these points only the northern element of change has been effective. The importance of this inferential extension of the Nipissing plane is apparent when we consider how greatly it extends the known area of subsequent deformation.

*The Isobases of Deformation.** We are now prepared to examine the map which accompanies this paper. The Nipissing beach is nearly everywhere very close to the present lake shore, and for this reason there would be no advantage, in a map drawn on so small a scale as this, in trying to represent that beach as an independent feature. The coast lines of the lakes are drawn heavier along all the shores where the Nipissing beach has been abandoned than elsewhere. In a few places, as towards North Bay, the beach passes inland, and the former outlet to the Ottawa valley is shown. The heavy broken line east of North Bay is a conjectural representation of the shores of the arm of the sea into which the outlet river emptied. Where the beach passes under the present level of the lakes, it is represented by a heavy broken line outside the present coast line. At the west end of lake Superior the depression represented is below that lake and not below the Huron plane, which is about 20 feet lower.

The straight lines drawn across the map from southeast to northwest are lines of approximately equal deformation. They are the "isobases" of Baron de Geer.† The lower line, AA, which passes from near Buffalo toward Duluth, is the node line or line of intersection between the Nipissing and the Huron-Michigan planes. Along this line the Nipissing plane is calculated to pass under the present level of the lakes toward the southwest. Each of the other lines parallel to AA passes through places which have undergone approximately equal

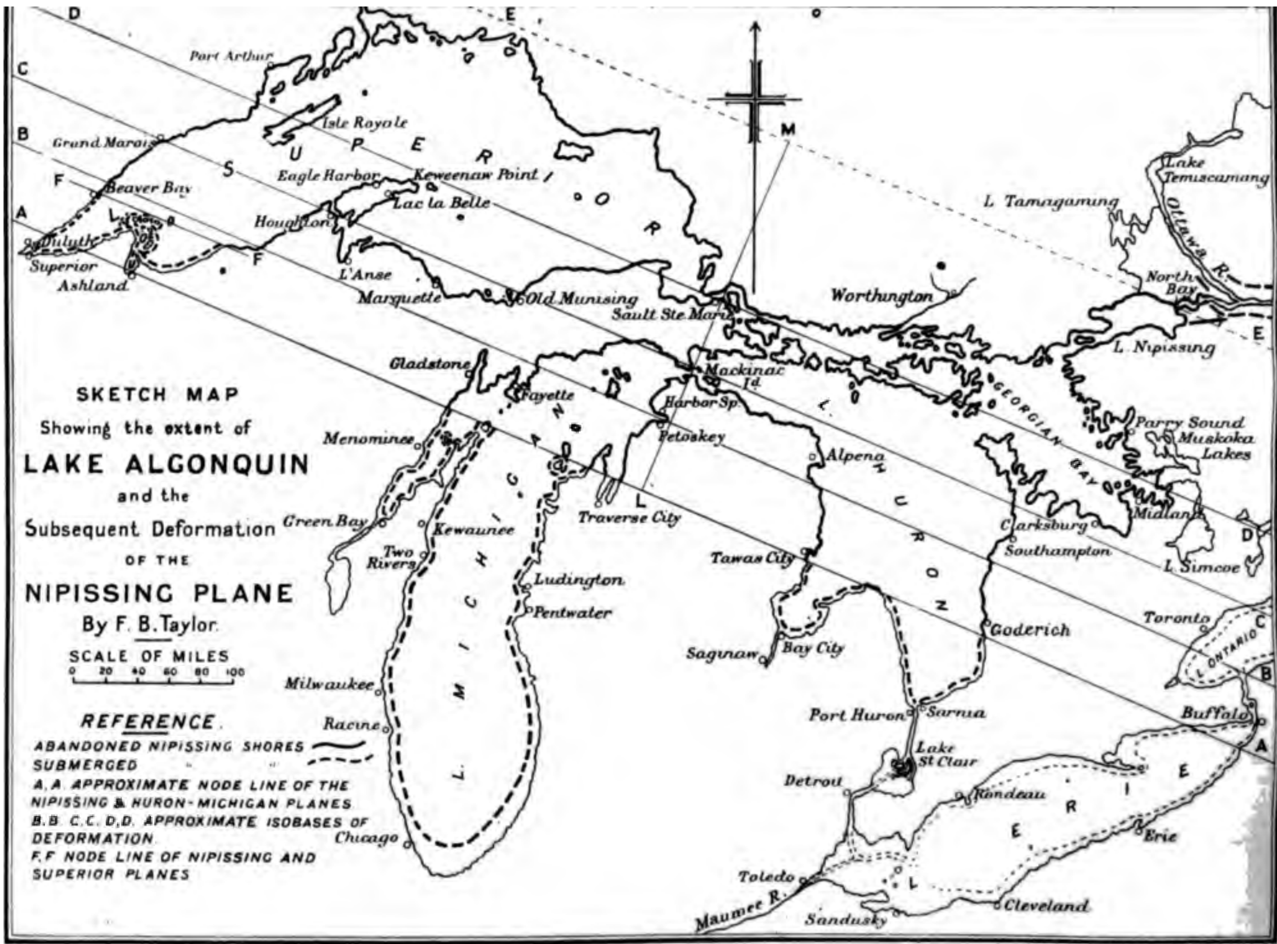
*It is only fair to state here that neither the field work nor the subsequent writing of the papers descriptive of it were in the slightest degree prejudiced in favor of the very uniform attitude and extension of the Nipissing plane as here described. It was hoped at first that only a simple and uniform northward rise would be found. But when the long rise from Duluth to North Bay was discovered, that idea had to be given up, and the observations henceforth were made without any preconception as to what the results were going to be. The real extent and attitude of the Nipissing plane was not worked out until after the first four papers had been published and the fifth sent to the editor, when the history of lake Algonquin was taken up as a special study.

†"On Pleistocene Changes of Level in eastern North America," by Baron Gerard de Geer. Proc. Boston Soc. Nat. Hist., vol. xxv, May 18, 1892, with map; AMERICAN GEOLOGIST, January, 1893.

amounts of deformation. The lines are all drawn straight; but it is not presumed that the points of equal deformation are really so exactly aligned. They are, however, very nearly so, and inasmuch as all the measurements, except a few by Spencer and Lawson, were made by aneroid, it seems useless to attempt a more exact representation. The discrepancies are nowhere greater than the probable limit of error in measurement, and the limit is small in this case. For in nearly all places the conditions of measurement were very favorable for accurate results. As to the line AA, all the nodal points are calculated; none were determined by observation. But the data for the calculations, so far as relates to lakes Michigan and Superior, are most of them good. Those on lake Huron are less certain. On Saginaw bay they are entirely conjectural. Only this single fact bearing on the case for that bay is at hand from observation: I have several times crossed the great flats of the Saginaw valley, and I regard it as certain that the Nipissing beach does not appear on the shores about its southern half. Some of Lawson's lower beaches on the northwest Superior shore and Spencer's on the east Huron and Georgian bay shores agree very closely with conjectural extensions of the Nipissing plane to those parts.

The direction of the isobases was determined in the first instance from the points of observation which lie along the line CC. On comparing the altitude of the Nipissing beach at all the different places where it was observed, and measuring their hights from the Huron plane, it was found that those at Mackinac, Gros Cap, Old Munising, Marquette and Houghton are almost exactly at the same hight, 45 feet; and further that, with the exception of Marquette, they are almost ex-

NOTE.—After the map which accompanies this article was ready for the process of reduction it was discovered that it was not drawn true to scale. The defect is in the original map from which this was traced. As it stands, the map makes east and west distances a little too great, but is not distorted in a north-south direction. The defect does not change the relation of the isobases to the places of observation, but slightly increases their angle with the meridian. Inasmuch as this paper is of a preliminary nature, based almost entirely upon aneroid measurements, and inasmuch as the map was originally intended to illustrate rather than to demonstrate, the defect is not considered to be of sufficient importance to warrant the delay necessary to make a new map. The distances and angles are correctly stated in the text.



THE SECOND LAKE ALGONQUIN.

actly on a straight line. A straight line was therefore drawn through Mackinac and Houghton and this line was taken as the first or fundamental isobase. On a comparison of the remaining points of observation off CC it was found that they could not be better represented than by straight lines parallel to CC. In this way BB and DD were constructed. The main part of the Nipissing plane so determined lies mostly between the isobases BB and DD, and it extends from Mackinac to Houghton. This area is 250 miles long and about 100 miles wide, if we count the distance to Gladstone and Fayette which lie south of BB. From the points observed in this principal area the place of the node line AA was calculated and its place so determined, is approximately parallel with the other lines. From this principal area, which comprises carefully measured parts of the Nipissing beach in each of the three upper lake basins, the Nipissing plane was produced in all directions and its relation to the various littoral features of the remaining parts of the lake basins were noted. Some of these will be described in detail later on. The mean rate of rise in the Nipissing plane from Petoskey to Sault Ste. Marie is little more than 6½ inches per mile. It will thus be seen that a difference of five feet in altitude is equivalent to nearly ten miles difference in the place of an isobasal line. Almost any of the measurements may be in error as much as five feet either way. It follows that the isobases may be ten miles in error either way at any place. But the extension of the measured plane over so wide a space, and especially its very close agreement with facts which point to its extension over several times that space in other parts, reduces the probable error very much and increases the value of the isobases. Facts in widely separated places prove that these lines are certainly not far out of place. Points of observation not situated on a line generally show an altitude which agrees with an extension of the plane between or beyond the lines. There are a few points that appear to be exceptions. All but one, however, are within the limit of error. Marquette and L'Anse seem a little too high and Midland a little low. North Bay alone is wide of the mark, being 40 feet higher than the main plane produced to that point. The rate of rise from Sault Ste. Marie to North Bay (transferred to M on the line EE) is nearly

one foot per mile. In this case it must be assumed that the plane actually changes its attitude in that direction. The distances between the isobases, and the rise in feet from each to the next, are presented below in tabular form.

Intervals.	Miles Distance.	Feet Rise.
AA to BB	45	25
BB " CC	36	20
CC " DD	45	25
DD " EE	95	90
AA " DD	126	70
AA " EE	221	160

The apparent discrepance from a true plane between AA and DD are all entirely within the limit of error. There is no reason to infer, for instance, that the 25 feet in 45 miles from CC to DD represents a real increase in the rate of rise. Prof. Lawson's levelling makes the beach at Sault Ste. Marie 49 feet above lake Superior, while that at Mackinac may be a little more than 45 feet above lake Huron, in which case the apparent extra rise would vanish. It is a fortunate circumstance that three of the best points of observation, viz.: Sault Ste. Marie, Mackinac, and Petoskey, are almost exactly on LM, the line of maximum rise of the main plane. Even after allowing liberally for such deviations as appear to be present, the fact still remains that the most remarkable feature of the Nipissing plane is its very close approach to uniformity over an extent of more than 700 miles or from Duluth to Buffalo. Following is a table of the altitudes of the Nipissing beach at the principal points of observation, all measured in feet from the Huron plane:

Pie Island (Lawson)	64 ?
North end Portage lake canal	50
Houghton	45
Eagle Harbor	60
Lac la Belle	60
L'Anse	37
Marquette	45
Old Munising	45
Sault Ste. Marie	70
Mackinac and Gros Cap	45
Fayette and Gladstone	20
Petoskey	25
Worthington, Ont., approx	130
North Bay	160
Midland	50

Wyebridge (Spencer)...........	55 ?
Clarksburg (Spencer).	45 ?

The node line passes a little south of Buffalo and a little north of Duluth. Near the center of the map its direction is N. 63° W. and the direction of maximum rise of the deformed plane at right angles to this is therefore about N. 27° E. But at the sides the meridians converge slightly northward. This agrees closely with the direction of the conjectural isobases for the region of Georgian bay as shown in De Geer's map of recent changes of level in Eastern North America.* Lake Superior is 20 feet higher than lake Michigan, and the node of the Nipissing plane should therefore be on a line about ten miles south of the isobase BB. This node is shown by the short line FF which passes through the outer Apostle islands and strikes the north shore at Beaver Bay. In his article on the Algonquin beach, Dr. Spencer says that Minnesota point at Duluth shows that the water there has been backed up to a higher level recently.† This view is undoubtedly correct, and the opinion expressed by me in discussing this feature in the fourth paper of the above list needs to be modified accordingly. The long Chaquamegon point near Ashland, Wisconsin, is another recent littoral bar of the same kind, and it is curious to note that both of these lie on the south side of the calculated nodal line of the Nipissing and Superior planes and that there are no other great littoral bars like them on the shores of this lake. This correction points to the conclusion that the Nipissing plane rises from Duluth to North Bay about 165 feet, instead of 125 or 130 as stated in the fourth paper. The isobase DD crosses Isle Royale and strikes the north coast of lake Superior about at Portage river. Isle Royale has many shore lakes like Lac la Belle, cut off by littoral bars. There is good reason to believe that the Nipissing beach is in its normal place on the north shore, as indicated by the projection of its plane from the southeast. And if it is there we cannot avoid the conclusion that the change which deformed it also carried all the other higher beaches up with it. Yet professor Lawson, as pointed out in the latter part of the fourth paper, infers that there has been no deformation of the

---

*Op. cit.

†"Deformation of the Algonquin Beach," etc., page 19.

lower beaches of that coast. But the methods which he used prevented the discovery of such deformation as may exist. By the projection of its plane from the south shore the Nipissing beach should be expected on the extreme northern shore at an altitude of 100 or 110 feet.

[*To be concluded.*]

EDITORIAL COMMENT.

An Amusing Error.

Our able and esteemed contemporary, *Nature*, has fallen into a rather amusing error in quoting an illustration from the first volume of the reports of the geological survey of Iowa. Prof. Calvin, in an illustration opposite p. 61, has represented the overhanging limestone at "the Cascade," Burlington, *in winter*. The cascade is frozen and the ice hangs from the edge as long stalactites with a mass of stalagmitic ice at the bottom. Perhaps from want of familiarity with so wintry a scene the writer in *Nature* has mistaken the ice for the limestone and adds words to that effect. Prof. Calvin says, "The limestone often stands out in overhanging cliffs over the softer Kinderhook beds," but in *Nature* we read, "The limestone often stands out in overhanging cliffs over the softer shale beds beneath and gives the appearance of a cascade, as shown in the accompanying illustration, which is reduced from a plate in the report."

Regarding the report itself our contemporary adds the following remarks, which from such a source are highly complimentary:

"The volume referred to in the foregoing note showed us that the publications of the Iowa survey were to be of a high character. The second volume goes to confirm this view. It is a description of the coal deposits of Iowa, by Dr. C. R. Keyes, and is a model of what such a report should be. With text running into more than 500 quarto pages, 18 full page plates of a high quality, representing interesting formations in connection with the Coal Measures, and over 200 figures in the text, the volume is an attractive handbook for the coal

miners of Iowa. * * * We offer our congratulations to Dr. Keyes and the geological corps with which he is associated." E. W. C.

THE FOSSIL FISHES OF CANON CITY, COLORADO.

A little more than two years ago, announcement was made by Mr. Walcott of the discovery of fish remains in a red sandstone of lower Silurian age, near Canon City, Colorado. The specimens were widely exhibited to the palæontologists of this country and, at the meeting of the International Congress at Washington, were not only generously displayed, but the opportunity of examining the locality of their occurrence afforded to, and accepted by many of the visiting geologists. Dr. Otto Jaekel, of Berlin, who had done some refined work in the microscopic study of fossil fishes, was invited to make a close analysis of these remains, and in a recent review of Walcott's paper entitled "Preliminary notes on the discovery of a vertebrate fauna in Silurian (Ordovician) strata" (1892), he has made some interesting observations (Neues Jahrbuch, 1895, p. 162) thereupon. "The first glance at the remains in question," he writes, "at once conveys the impression that they are much more closely related to Devonian than to any Silurian fishes as yet known." Some of the scales are stated to undoubtedly belong to the *Holoptychiidæ*, other fragments are to be ascribed to the placoderms. "The question is now this; whether these remains are really of lower Silurian age. Upon visiting the locality in 1892, many European geologists were, like myself, convinced that the stratigraphic relations at this place are not simple and readily made out, as the strata have been greatly dislocated by faults. So there seems to be at least a possibility that Devonian sandstones are lying between those of lower Silurian age, although the immediate proximity of lower Silurian fossils in a petrographically similar sandstone and the absence of other Devonian fossils in the fish-bearing strata does not support such a suggestion. Still its possibility is strengthened by the fact that, if I am correctly informed, there are red Devonian sandstones in the neighborhood of Canon City, and its probability shown by the character of the fossils themselves." J. M. C.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Ueber Porocystis pruniformis Cragin (? Araucarites wardi Hill) aus der unteren Kreide in Texas; by HERMANN RAUFF (Neues Jahrbuch für Mineral, etc., 1895, Bnd I, pp. 1-15, pl. I.)

Robert T. Hill was the first to notice, under the name *Goniolina* (1889) these peculiar spherical or ovoid bodies which, in 1893, he described in some detail as the cones of an araucarian, designating them as *Araucarites ? wardi.* In the latter year also, Prof. F. W. Cragin, regarding the fossils as bryozoan, described them under the name *Porocystis pruniformis.* Dr. Rauff's analysis, based upon a few internal casts, substantiates neither of these opinions, but indicates certain superficial similarities between the surfaces of such internal casts and representatives of the genus *Receptaculites.* "On the spherical form and mosaic structure of the surface we cannot place much weight. They are unessential similarities, for *Porocystis* shares them with other and wholly distinct organisms. But we may ascribe some little value thereto, from the fact that bodies like the *Receptaculitidæ* are constructed of numerous homomorphic elements (Merones), each of which consists of a thickened summit expanded into a plate and a longer or shorter radial, perforated by an axial canal, and that these radials (so far as our observations permit us to judge) swell at their proximal ends until they rest against and crowd one another. Radials of quite similar form we have found in *Receptaculites*, as well as in some of the *Ischadites.*" The author ventures no further opinion in regard to the structural portion of these fossils, leaving this determination contingent upon the acquisition of more complete material. J. M. C.

Ueber das Oberdevon der Ostalpen, III; Die Fauna des unterdevonischen Riffkalkes, I. By FRITZ FRECH, with the assistance of E. LOESCHMANN. (Zeitschr.der deutsch. geol Gesellsch., vol. 46, pp. 446-479, pls. 30-37, 1894.) This is the first instalment of descriptions of the Devonian faunas of the Corinthian Alps, whose geology has already been carefully expounded by Prof. Frech in various numbers of these proceedings, and, more recently in book form; "Die Karnischen Alpen." The species here described are largely gasteropods of various genera, out of 51 species, 37 belonging to this group. Their variety is interesting, if not remarkable, evincing, first, an abundant representation of the capulids (*Platyceras* and *Platyostoma* = *Diaphorostoma*, Fischer, 10 species and varieties) in harmony with other lower Devonian or "capulian" faunas; five examples of the Silurian genus *Tremanotus* (better *Trematonotus*); typical forms of *Bellerophon*, of *Bucanella* and *Oxydiscus*, with representatives of the genera, *Pleurotomaria*, *Murchisonia*, *Triangularia* (a new genus having the form of a triangularly pyramidal *Solarium*) *Euomphalus*, *Polytropis*, *Trochus*, *Loxonema*, *Polytropis*, *Macrochilus*, *Philhedra*, *Horiostoma* and *Turbonitella*. J. M. C.

The American Tertiary Aphidæ, with a list of the known species and tables for their determination. By SAMUEL H. SCUDDER. (Thirteenth An. Rep., U. S. Geol Surv, Part II, pp. 341-366, with plates CII-CVI.) Thirty-two species of plant-lice. representing fifteen genera, all regarded as distinct from any now living, are found in Tertiary strata at Florissant in Colorado, Green River in Wyoming, and Quesnel in British Columbia. Though one might suppose, as the author remarks, that the delicate, gauzy texture of the wings and the softness of the bodies of these insects would scarcely permit their preservation in the rocks, they are so plentiful at the locality first named that it has yielded more than a hundred specimens which have been examined by the author. As a whole, these Tertiary genera and species differ most remarkably from those of the present day in the great length and slenderness of the stigmatic cell of the wings. In the plates the fore wings of all our known fossil species are figured on an identical scale, reversed when necessary to represent all of them as left wings, and with deficiencies in the outlines and neuration supplied by conjectural dotted lines. Besides Tertiary Aphidæ in Europe, two or three specimens of Mesozoic age have been found in England; but these mostly are allied to present genera, not having the extraordinary features of the American fossil forms.

W. U.

Granites and greenstones: a series of tables for students of petrology. By FRANK RUTLEY. (8vo, 48 pp.; London, Thomas Murby, 1894.) The first of the tables is a tabular classification of eruptive rocks, in which the essential minerals of each rock are placed with the name. Following this the various rock structures are defined, and a short description of each rock species is given, the description including not much more than its place in the scheme of classification, the structure and the essential, accessory and secondary constituents. The last tables are determinative mineralogical ones; they differ from other tables of this nature in that chemical formulæ and specific gravities are omitted, and the tables are cleared of other matter which does not relate to simple microscopic investigation. This little book will prove useful to students and teachers; one of the features which especially commends it is its easily accessible and concise descriptions of the various rock species.

U. S. G.

On the banded structure of some Tertiary gabbros in the Isle of Skye. By ARCHIBALD GEIKIE and J. J. H TEALL. (Quart. Jour. Geol. Soc., vol. 50, pp. 645-659, pls. 26-28, Nov., 1894.) Banded structures are known in basic igneous rocks from several localities, perhaps the best developed instances being in the gabbros and anorthosites of the Adirondacks, of Canada, and of the Lake Superior region. In the gabbros of the Isle of Skye this structure, as shown by the descriptions and photographs which accompany the paper, attains a remarkable degree of perfection. These banded gabbros are coarse-grained rocks composed of pyroxene, plagioclase, olivine and titano-magnetite; the banding is due to a variation in the relative proportions of these four essential constituents, the lighter

colored bands being rich in feldspar, and the darker rich in the ferro-magnesian constituents and magnetite. There is no essential difference between the different bands as regards coarseness of grain, and the individual minerals interlock with each other across a junction line just as they do in the central portions of the bands. It therefore seems impossible to account for the banding by the successive injection of magmas of varying composition, and, as cataclastic phenomena have not been observed, the authors conclude that the cause which produced the banding must have operated before the crystallization of the minerals. They consider the banding as the result of a heterogeneous magma. The analogy between these banded structures in the deep-seated basic rocks and some of the bandings in the ancient gneisses, especially the Lewisian gneiss of northwestern Scotland, is clearly pointed out, and it is shown that the causes which produced the former may justly be considered as applicable to the latter. "In view, however, of the undoubted evidence of secondary dynamic action in many regions, and in the absence at present of any well established criteria by which we can in all cases discriminate between original and secondary structures, we are not yet in a position to define the exact limits within which the hypothesis of the intrusion of heterogeneous magmas is applicable to the explanation of the Lewisian gneiss."

This paper presents one of the many facts which, in recent years, have led most geologists to conclude that many of the parallel structures in the ancient gneisses are not necessarily due to original sedimentary deposition, but can be explained equally well, or better, on other hypotheses; still, there remain some who find it difficult to consider banding in gneisses as anything but good evidence of a sedimentary origin for these rocks. U. S. G.

RECENT PUBLICATIONS.

I. Government and State Reports.

Proc. U. S. Nat. Mus., vol. 17, No. 1002. Discovery of the genus Oldhamia in America, C. D, Walcott.

Geol. Sur. of Alabama, Eugene A. Smith, State Geologist. Geological map of Alabama, with explanatory chart, 1894.

Bull. No. 5. Illinois State Mus. Nat. Hist. New genera and species of Echinodermata, S. A. Miller and Wm. F. E. Gurley, 53 pp., 5 pls., Dec. 20, 1894.

II. Proceedings of Scientific Societies.

Proc. Boston Soc. Nat. Hist., vol. 26, pts. 2-3, 1894, contains: Facetted pebbles on Cape Cod, Mass., W. M. Davis; Some typical eskers of southern New England, J. B. Woodworth: On the distribution of earthquakes in the United States since the close of the Glacial period, N. S. Shaler: The geographical development of alluvial river terraces, R. E. Dodge; The preglacial channel of the Genesee river, A. W. Grabau; A speci-

men of *Ceratiocaris acuminata* Hall from the Waterlime of Buffalo, N. Y., G. W. Stone.

III. Papers in Scientific Journals.

Jour. of Geol., Sept.-Oct., 1894, contains: The Cenozoic deposits of Texas, E. T. Dumble; Outline of Cenozoic history of a portion of the middle Atlantic slope, N. H. Darton; The Metamorphic series of Shasta county, California, J. P. Smith; Superglacial drift, R. D. Salisbury.

Amer. Naturalist, Oct., 1894, contains: The duration of Niagara falls, J. W. Spencer.

Ottawa Naturalist, vol. 8, No. 6, Sept., 1894, contains: Notes on the "Quebec group," T. C. Weston; Notes on fossils from Quebec City, Canada, H. M. Ami.

Canadian Record of Science, vol. 5, No. 8, contains: Description of two species of ammonites from the Cretaceous rocks of the Queen Charlotte Islands, J. F. Whiteaves; The World's Geological Congress, H. M. Ami.

Amer. Jour. Sci., Nov., 1894, contains: Origin of bitumens—a retrospect, S. F. Peckham; Study of the cherts of Missouri, E. O. Hovey; Copper crystals in aventurine glass, H. S. Washington.

IV. Excerpts and Individual Publications.

Fossil Salvinias, including description of a new species, by Arthur Hollick. Bull. Torrey Botanical Club, vol. 21, pp. 253-257, pl. 205, June, 1894.

The Preglacial channel of the Genesee river, by A. M. Grabau. Proc. Boston Soc. Nat. Hist., vol. 26, pp. 359-369, Sept. 8, 1894.

Ore deposits of Camp Floyd district, Tooele county, Utah, by R. C. Hills. Proc. Colorado Sci. Soc., 12 pp.

V. Proceedings of Scientific Laboratories, etc.

Bulletin, Dept. of Geol., Univ. of California, vol. 1, No. 5, contains: The lherzolite-serpentine and associated rocks of the Potrero, San Francisco, Charles Palache. No. 6 contains: On a rock from the vicinity of Berkeley containing a new soda amphibole, Charles Palache. No. 7 contains: The geology of Angel island, F. L. Ransome; A note on the radiolarian chert from Angel island and from Buri-buri ridge, San Mateo county, California, G. J. Hinde.

CORRESPONDENCE.

"CEPHALOPOD BEGINNINGS." In the December (1894) number of "Natural Science," Dr. F. A. Bather has generously devoted considerable space to a critical review of some of my recent papers pertaining to early stages of cephalopod shells, all of which have been published in the AMERICAN GEOLOGIST.* So important do the primitive shell-characters in this group of beings appear, that such a review from so well-equipped

*The Protoconch of Orthoceras, XII, pp. 112-115, 1893; The Early Stages of Bactrites, XIV, pp. 37-43, 1894; Nanno, a new Cephalopodan type, XIV, pp. 205-208, 1894.

a writer is very welcome to me, the more as my observations of facts are not called into question. If Mr. Bather's interpretation of these facts differs from my own, it may enable us the sooner to get at the full significance of these structures.

Bather's paper, entitled "Cephalopod Beginnings," and covering some seventeen pages of the magazine referred to, is bright, logical and incisive. I am fully alive to the force of his arguments, which, for such readers as may care to follow this subject, may be briefly summarized thus: From the primitive cephalopod ancestor of "far pre-Cambrian times" have been derived along divergent lines the three orders, Nautiloidea, Ammonoidea and Coleoidea (Bather's term for the Dibranchiata). These three may be divided into two groups, one in which the protoconch was always fragile and is altogther lost; these are the Nautiloidea. The others had a stronger and calcareous protoconch and have retained it, either with the shell coiled about it, or enclosed within secondary depositions; these are the Ammonoidea and Coleoidea. The observations which I have made in the first two of my papers militate against this proposition, and have, hence, invited attack; but I cannot help feeling that Dr. Bather's argument is rather procrustean inasmuch as his division of the Cephalopoda based upon the destructibility of the protoconch was proposed some years before this later evidence was adduced. It has been argued by me that the protoconch described in the first of my papers is that of *Orthoceras* and that the structure of *Bactrites* as recounted in my second paper and evinced both in its protoconch and the position of its septal funnels distinctly shows its orthoceran affinities. There are some side lights upon the evidence adduced by me in regard to these protoconchs which it will be pertinent now to direct upon the subject.

The orthoceran character which, in confirmation of the views of some of the older palæontologists who knew nothing of its protoconch, I ascribe to *Bactrites*, hinges to some degree upon the generic character of the protoconch-bearing shell regarded by me as *Orthoceras*. It has been already explained that this little protoconch with the first two septa attached, was found in a Devonian limestone (Styliola layer of the Genesee shales), that its general aspect, the circular conch, the central position of the sipho on the last septum (I have shown that it is lateral in *Bactrites* from the very beginning) and the absence of any deflection of the conch as in the Ammonoidea, including even *Mimoceras* and *Agoniatites*, all make for *Orthoceras*. When my description of this fossil was first prepared I ventured to ask Prof. Hyatt to examine my observations and drawings, feeling that in so doing I took the case directly to the court of last resort. It was not the *Orthoceras* of his observations and he certainly expressed himself at first as doubting the pertinence of that generic reference, still conceding many of the orthoceran characters of the specimen. His position in regard to it then was similar to that of Bather now, involving even the suggestion that, as it was quite palpably not the protoconch of a goniatite, it might be that of some otherwise unknown ammonoid genus. This argument is a good one either from

the point of view taken then by professor Hyatt or now by Dr. Bather; but, though appreciating its premises, I am nevertheless impressed by its serious improbability. The possession of this fossil was not a mere incident. By assiduous effort and by every mechanical and chemical contrivance known to me, I have for many years endeavored to wring the fossil contents from this heretofore little studied formation of the Genesee shales. This is one of the results, and while, among the others, cephalopod protoconchs and protoconch-bearing shells abound, it would, I submit, after this protracted effort, be somewhat less than likely that a genus of cephalopods in these faunas should still be known by its protoconch alone. There are here *Manticoceras*, *Gephyroceras*, *Tornoceras*, and perhaps some other forms of the goniatites, *Clymenia*, *Bactrites*, *Gomphoceras* and *Orthoceras*. The possible variations in the form of the protoconch within the limits of a group of allied genera or even of a given genus are not yet satisfactorily established. From our present knowledge and presumably, they are not great. This protoconch is assuredly not that of any of the goniatitine genera mentioned, nor of *Clymenia*, which I have fully described, nor that of *Bactrites*, unless these primitive shells vary in all essential particulars with the species. One may readily admit the suggestion of Bather that many of the things termed *Orthoceras* may prove to be something else than typical orthocerans: I may, however, remark from my knowledge of the orthocerans of this fauna that they have not evinced any dissimilarity from such typical forms.

A recent expression from Prof. Hyatt conveys the impression that the facts above stated and the evidence from the fossil itself which he has since examined has somewhat modified his opinion. In his latest and very remarkable paper, the "Phylogeny of an Acquired Characteristic," he writes (p. 361): "Clarke has recently shown that a straight, Orthoceras-like shell may have a complete egg-shaped protoconch like that of Bactrites. His form certainly has the characters of an Orthoceras, but the protoconch is large and like that of the Ammonoidea. The shell may be transitional from Orthoceras to Bactrites but is probably not a typical form of Orthoceras." At this writing I believe that Prof. Hyatt did not have before him my account of the "Early Stages of Bactrites," and I must here rehearse the fact, the force of which Bather himself seems not fully to have recognized, that the whole and entire argument for regarding *Bactrites* as a straight ammonoid shell rests upon Branco's determination of a *Mimoceras*-like protoconch in shells which *he believed to be Bactrites*, but whose mature characters were unknown. Herein the material described by me has a decided advantage: it was abundant and its characters at every growth-stage from inception to maturity are known, its later phases showing it to be in full agreement with the species upon which the genus was founded. Disavowing any intention of casting doubt upon the observations of Dr. Branco, I think it clear that the *Bactrites* which have been described by me are a step further away from the Goniatitinæ and nearer the nautiloids than the *Mimoceras*-like shell described by him. The New York specimens of *Bactrites*

seem to me to very substantially strengthen Hyatt's conception of the common straight orthoceran ancestor of both nautiloids and ammonoids, and there is no closer approximation to, or expression of, this radicle than in the nautiloid shells of the Lower Silurian which I have recently termed *Nanno.*

In regard to this genus, *Nanno*, I may venture to say on my own behalf to my various kindly reviewers that in the brief and preliminary description of the Minneapolis shells I did not believe myself to be ignoring the work of Holm upon similar shells which he referred to *Endoceras*, knowing that the opportunity would soon be afforded of doing it fuller justice in a more lengthy account of the Minnesota Silurian cephalopods, and I am sorry if offense has been given by my apparent omission. *Nanno aulema*: none will, at least, deny its euphony, and to the suggestion in the December number of this journal that the name is inappropriate to a genus of cephalopods, it may be remarked that the good old terms *Loligo* and *Sepia* are pleasingly discordant with the recent spondaic terminology of these creatures. No one familiar with the structure of typical *Endoceras* will long stand out for the generic identity of the two. But what place is there for *Nanno* in Dr. Bather's two-fold division of the Cephalopoda; the "Lipo-protoconchia" and the "Sosi-protoconchia;" the former "practically coextensive with the Nautiloidea," "which, starting with a very fragile protoconch, soon lost it altogether," the latter, "starting with a stouter protoconch" and preserving it as in the Ammonoidea and Dibranchiata? Would Bather have *Nanno* with its immense protoconch not a nautiloid, and its close allies, *Endoceras*, *Cameroceras* *Vaginoceras*, *Piloceras*, all not nautiloids? Or would he, by leaving it outside the pale of both of his divisions, regard it as a near expression of the ancestral form of both? The latter seems, as already observed, nearer the correct interpretation of the structure: but it does appear to coincide with Bather's view which is stated thus: "We are therefore not entitled to say that the Ammonoidea were derived from the Nautiloidea, although we may not doubt that all three orders sprung from a common ancestral stock first evolved in far pre-Cambrian times." J. M. CLARKE.

EROSION DURING THE DEPOSITION OF THE BURLINGTON LIMESTONES. In the October number of the GEOLOGIST (1894), I put forward some evidence to show that there had been a cessation of deposit during the building up of the Burlington limestones, and that erosion took place, followed by a renewal of deposition. I will now describe strata lying in an inclined position with all surroundings going to show that they were thus deposited and that the inclination is the result of previous erosion.

The locality is about three miles north of the city of Burlington in the bluffs along the valley of Flint river. This is rather a small stream which traverses the country diagonally from the northwest to the southeast. The bluffs are quite prominent and in some places very abrupt, although deeply covered with loess and drift. The north bluff is frequently broken by deep ravines in which, at a number of places, rock

exposures are displayed. However, the mantle of drift is so heavy—being from 20 to 50 feet—that it is difficult to find exposures of any great length. One of those in evidence is the longest within a radius of a mile.

One of the ravines spoken of comes into the valley through the bluff from a due northerly direction. It is very broad for about a quarter of a mile back from the face of the bluff. It then forks, being formed by two smaller ravines which come together, one from the northeast and the other from the northwest. The bottom of the main ravine is but little above the level of the Flint valley, while the tributaries are much higher and descend very rapidly, thus showing their comparatively recent origin. In the fork between the smaller ravines the rock is exposed on both sides at some distance back from the junction. The exposure

in the northwest tributary is much the better one and is that which appears in the cut. This shows about 60 ft., which is not more than half the length in view. The depth is 10 ft. It will be seen from the cut that the strata dip quite rapidly. The angle is from 10° to 12°. This is uniform for the full length of the exposure and probably extends to the extreme end of the point, which is not more than 50 yards away, but it is hidden by the loess and drift. The angle of dip would bring the inclined strata to the level of the bottom of the main ravine just below the junction of the tributaries.

This inclination of the strata is purely a local feature, for, 25 or 30 rods farther up the ravine, the same rock appears in a perfectly horizontal position, although of course at a higher level. Also at several other places within a radius of a mile I have seen the same rock and always without

any perceptible dip. There is nothing to show that the strata have ever been tilted or distorted in any way. They seem to lie just as they were deposited. The inference is that there must have been erosion preceding their deposition. It would also indicate that the Flint valley and the main ravine must have already had an existence. It seems like presumption to try to place the origin of the drainage system at so early a date as the middle of the Upper Burlington epoch, but the evidence points too strongly to ignore it. I called attention to this fact in my previous article on this subject. As determined by fossils, this rock lies but a few feet above the bed at the Cascade quarries which furnished such conclusive evidence of erosion. The two localities are only about 6 miles apart and it seems quite certain that the time of erosion was the same for both. FRANCIS M. FULTZ.

Burlington, Iowa.

VOLCANIC ASH BED NEAR OMAHA. I believe I have never informed you of the discovery of a volcanic ash-stratum in the bluffs of the Missouri 7½ miles north of Omaha. It is 18 inches thick, with clearly defined upper and lower limits, about 40 feet above low water in the river. It lies in the lower clayey portion of the loess, about 6 feet above its well marked base, where it rests on the horizontal surface of drift gravel at least 20 feet in thickness, and, judging from other exposures near by, underlaid by till. The loess rises 30-40 feet above the ash layer, and there is no sign of disturbance since the deposition of any of the formations.

The ashes are more tinted with iron oxide than in other localities I have seen, but Mr. J. S. Diller, of the United States Geological Survey, pronounces it clearly identical in character with that before submitted to him from Knox, Cumming and Seward counties of Nebraska. I have not yet found the layer on the Iowa side of the river, though I have examined several similar localities.

I hope sometime to find time to work up some of these subjects into shape suitable for publication. J. E. TODD.

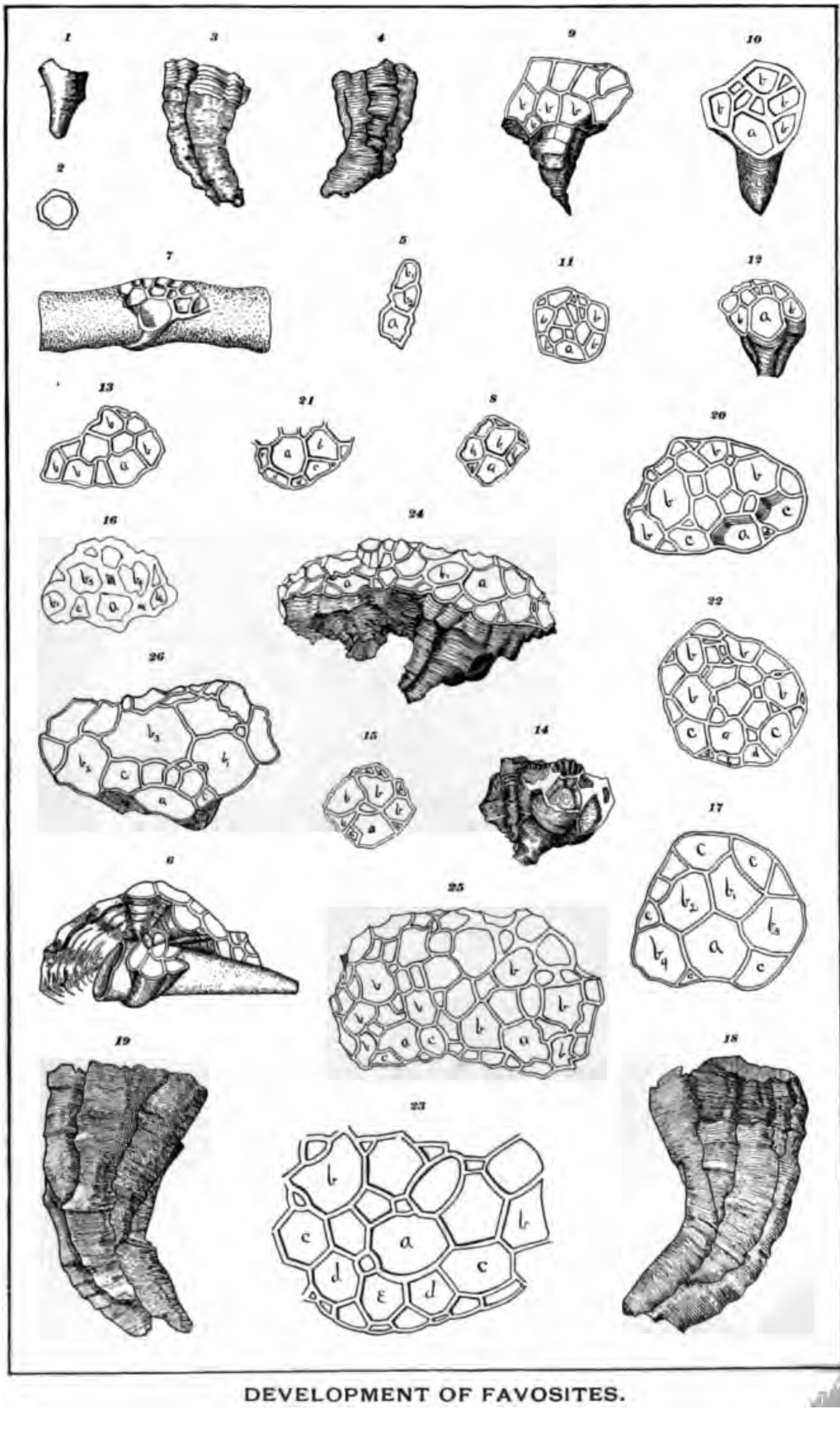
Tabor, Iowa, May 12, 1890.

PERSONAL AND SCIENTIFIC NEWS.

Prof. W. W. Clendenin has been appointed state geologist of Louisiana, at the same time holding the place of professor of geology and mineralogy in the State University. He will conduct the survey on the plan of Prof. Smith in Alabama.

PROFESSOR JAMES HALL HAS RECEIVED a medal and diploma of foreign membership from the "Regia Lyncei Academia," of Rome, in recognition of his services to geological science. This Academy was instituted in the year 291 A. D. and is by far the oldest of existing learned associations.

[NOTE.—The report of the Pleistocene papers of the Baltimore meeting, G. S. A., is deferred till the March No.]



DEVELOPMENT OF FAVOSITES.

THE

AMERICAN GEOLOGIST.

VOL. XV. MARCH, 1895. No. 3.

DEVELOPMENT OF THE CORALLUM IN FAVOSITES FORBESI, VAR. OCCIDENTALIS.*

BY GEORGE H. GIRTY, New Haven, Ct.

One American representative of *Favosites forbesi* from the Wenlock limestone of England is the variety *occidentalis*. The type specimen described by Prof. Hall in 1879,† as well as the material on which the present paper is based, were found in the Niagara shales of Waldron, Indiana.

The varietal differences in these two forms are considerable. In the American species the corallum is small, usually not over 6 cm. in diameter, and the shape pyriform or hemispherical, thus differing slightly from *F. forbesi*. The individual cells, moreover, vary from 1 to 3 mm. in diameter,† while, in the English variety, they range from 5 to 2 mm.‡ In the original description of *F. forbesi*, Edwards and Haime do not mention the character of the mural pores, yet the figures indicate that these are small and closely set, with ten or twelve rows to a corallite. In the variety *occidentalis*, however, they are of large size and widely separated, both laterally and longitudinally. It is rare to find more than one row between any two corallites, and occasionally none appear to be present. The strongly pustulose character of the cell walls seen in British specimens has not been observed in American forms.§

*Acknowledgements are due Dr. C. E. Beecher for the use of material, as well as for valuable suggestions in the preparation of this paper.

†Hall, 1879. Geology of Indiana. II Annual Report, p. 229.

‡Edwards and Haime, 1850-54. British Fossil Corals, p. 259.

§H[illegible]ology of Indiana. II Annual Report, p. 230.

THE CORALLUM.

The corallum of *Favosites forbesi* var. *occidentalis* begins with a single corallite, as in *Pleurodictyum*,* and attains a maximum size of 6 or 7 cm., having in general a globose or pyriform shape. Increase takes place by lateral and interstitial growth. Although the two modes of growth are really identical, for convenience the development of each will be treated separately, and for the same reason the regular increase of the colony has been separated into different stages.

In all representatives of this genus, and in *F. forbesi* no less, new buds are introduced regularly in the angles between older corallites. The practice is only a little less determined when the buds are introduced about the periphery instead of in the body of the corallum. This habit, nearly as much as the examination of specimens, has led the writer to distinguish different stages in the growth of young coralla and to assign to each stage later than the second a definite number of cells. These particulars are at present minor details, and have little or no bearing on the main points of this paper.

STAGE I.—The first stage consists of the initial cell alone. This at first is conical, but later becomes pyramidal or prismatic in form through the pressure of adjacent corallites. During this stage it is also slightly curved, so that a dorsal and a ventral side may be distinguished. Subsequent growth appears to be straight.

The initial cell is usually procumbent and attached firmly to some object of support. The side of attachment is most commonly the dorsal, more rarely the lateral, but never the ventral side. This upturning of the corallite is probably due to an attempt of the polyp to rise into a position favorable for food and growth.

Only two specimens belonging to this stage have been observed. In many young colonies, however, the initial corallite, together with the point of attachment, show plainly through the epitheca, thus rendering it possible to determine with some certainty the relative ages of many of the peripheral cells.

STAGE II.—When the initial corallite has attained the length of from .5 to 1 mm., it gives off four buds (*b*). This

*Beecher, 1891. Trans. Conn. Acad., vol. VIII., p. 207.

constitutes the second step toward the completion of the mature corallum. These buds spring invariably from the dorsal or attached side, for, at this stage, the corallite has bent upward in its growth sufficiently to allow budding on that side. The appearance of the buds is rarely simultaneous, but usually successive, and a regular alternation seems to be the rule. Occasionally in a very robust individual, the interval between the appearance of the first and second buds was much reduced. As a result b_1 and b_2 appeared simultaneously, and a little later b_3 and b_4. Each bud is connected with its parent by a pore, and the connection is maintained and continued upward by a row of pores.

STAGE III.—The next step in the growth of the corallum is the introduction of five new buds (c) in the peripheral spaces between those already existing.

STAGE IV.—During the fourth stage, ten buds (d) are given off on the periphery between each of the older cells.

STAGE V.—This stage consists of nineteen buds situated as before. At this point the original corallite is completely surrounded, while further growth takes place regularly along lines already indicated.

THE INTERSTITIAL CELLS.

As interstitial buds can appear only when divergence of the older corallites permits, the order of their appearance is subject to great irregularity, but, in a general way, they may be said to arise, like the peripheral buds, in the angles where the older corallites (in this case three in number) meet. The subjoined table gives the number of interstitial and peripheral cells regularly produced at each stage:—

Stage.	Peripheral.	Interstitial.	Total Periph.	Total Interst.	Total of all.
I........	The initial cell.				1
II........	4	0	4	0	5
III........	5	3	9	3	13
IV........	10	14	19	17	37
V........	19	52	38	69	108

The first set of interstitial buds consists of three cells, and is nearly contemporary with the third series of peripheral buds, only slightly preceding it. The central bud of the three is often much older, appearing nearly simultaneously with the second generation.

The diagram on Plate II, figures 1, 2, 3, 4, 5, represent stages in the development of *Favosites forbesi*, symmetrically considered.

Two groups may be distinguished among the colonies just discussed. In one, the initial cell is strongly upright, with but a slight surface of attachment. From this there results a corallum elongated in form, and much resembling a Cyatho-phylloid in appearance. No specimen with this characteristic has been observed still attached.

The other form occurs in greater numbers. Individuals representing it are found attached to crinoid columns where they ultimately form a ring about the stem. They have also been observed upon ramose forms of Bryozoa. The initial cell, as well as the five or six corallites next produced, are prostrate upon the surface of support, becoming resurgent only when the first bud is formed. This variation seems to be the direct result of conditions which surround the coralla. As the acute-conical shapes were presumably in a place less favorable for growth, they assumed an upright position and direction. The other form, the explanate almost incrusting one, being thrown by chance upon an advantageous place, assumed temporarily a resupinate mode of growth.

Thirty-eight coralla have been found nearly entire, and in a state of good preservation. The development from the initial corallite through two or more generations of buds can thus be traced out with considerable certainty. Of these coralla, three were younger than the completed second stage. Of the remaining thirty-five, four produced three, and thirty-one produced four peripheral buds as the second stage, and in every instance, these buds appeared on the dorsal side. Those features, therefore, which constitute perhaps the only new and important points brought out in this paper seem to be well established.

Irregularities in the development just outlined are not so great as to preclude reduction of the whole to a general system. By comparing irregular colonies with more symmetrical ones, an ideal law may be detected toward which all are tending. And so the word law may be used in connection with the development of coralla, but only in this sense, that certain buds habitually appear in certain symmetrical posi-

tions, while others sometimes accompany them, but without system or order.

In the development of these coralla, two elements can be readily distinguished, viz.: the initial cell with the four buds which it produces, making a well-defined group: and the true peripheral and interstitial buds, whose number and position are largely dependent on the number and position of the first. The character of the former group may vary in different species of *Favosites*. The secondary corallites may be more or less than four, and may be differently disposed about the initial cell, but the law governing the introduction of the other buds is both obvious in its nature and apparently the same throughout the genus. In *Favosites forbesi* the four secondary buds seem to form a constant increment of augmentation which each individual in the colony tends to perpetuate. Several instances have been noticed, one of which is figured on plate VIII, figure 24, where a polyp, separated for some reason from the rest of the corallum, has produced four buds from its dorsal side in the same manner as the primitive corallite. All the so-called irregularities have been manifestations of the same tendency. That this number is in most instances reduced to one or two in crowded colonies seems to be due to the rapidity with which one generation succeeds and closes over another.

In the appearance of the first four buds, no one order predominates. The four possible arrangements have all been observed, and in nearly equal proportions. A few instances have been met where the initial corallite developed but three buds in the second series. After a careful inspection of all undoubted examples of this occurrence (plate VII, figure 26) it is evident that the two outer buds are the oldest, and that all three are of unusual size. The space available for growth having been thus defined and partially occupied by the two outer cells. and the inner bud, the first to appear, having usurped the rest, the remaining bud was forced either not to be developed, i. e., to appear as a pore, or to come in as an interstitial cell.

In regard to the parentage of the peripheral buds as a whole, there can be no question. inasmuch as they are by definition external, and their origin and growth can be made out on any

well-preserved specimen. It might be asked, however, whether the buds which ultimately surround the initial cell are not immediately given off by it. This does not appear to be the case, both from the long interval which separates their appearance from that of the first four, as well as from the general law which governs the introduction of new cells. Moreover, a partially developed corallum was dissected by the writer, by means of acids, and the basal pores of such buds as were developed were found to pass into cells of the series *b* and *c*, and not into the initial cell.

The number of interstitial cells has already been seen to vary considerably, depending as they do upon the position and development of the other corallites. Their own position seems to be due to the general crowding of the colony. Those cells which are interstitial between the first and second generation, spring from the first, those between the second and the third from the second, and so on. Not only has this been observed in the single specimen dissected, but it also agrees with the strong unilateral tendency which is exhibited in other ways. In general, it may be asserted that the oldest cell buds first, and that the cells of other generations send off buds in the order of their ages. Thus the order of the whole corallum is in a measure predetermined by the order of the four buds constituting the second generation. The period at which the initial cell is completely surrounded varies slightly in different coralla. It is evidently dependent on the rapidity with which the enveloping buds, especially the final pair, increase in size.

Specimens showing stages in the growth of *Favosites forbesi* are figured on plate VII, figures 1-26; plate VIII, figures 23, 24 and 25.

Favosites spinigerus Hall.

This species is less abundant, and less satisfactory for study than *Favosites forbesi*, although obtained from the same locality and in the same preservation. In its development, it is closely allied to the species above discussed. The initial cell produces four buds from the dorsal side, as in *F. forbesi*, but, through prolific budding, these are generally separated by a large number of interstitial cells. Subsequent growth is more dorsal than in *F. forbesi*, so that, in all the specimens ex-

amined, the initial corallite retains a peripheral position. This peculiarity in the development of *F. spinigerus* is illustrated on plate VIII, figures 6-15.

Favosites conicus Hall.

Only three specimens have been secured which afford any evidence as to the earlier stages in the development of this species. They were obtained from the Delthyris Shaly limestone of the Lower Helderberg group in Albany county, New York. Figures 17, 18 and 19 of plate VIII represent the lower or epithecal surface of these specimens, which seem to show the initial cell of the corallum, together with the cells next produced.

The initial cell may be determined not alone by its larger size, for that character proves to be sometimes misleading when employed as a sole criterion for estimating the relative ages of corallites, but also by the shape of the theca. Where the corallites are all of the same age, or all mature, mutual pressure causes them to yield equally from their naturally cylindrical form, one not more than another. When different ages are represented, crowding causes the younger cells to be more distorted than those older. Consequently, in a section taken across the corallum at a point before the secondary cells had reached maturity it will appear that the initial cell is comparatively round, but the four secondary cells, while rounded on the outer side, are laterally compressed, and abut squarely on the initial cell. A third consideration to be entertained in orienting young colonies, in default of a better way, is that of symmetry, which appears to be a constant factor in the development of coralla. Thus, when the character of the material does not permit of determining the initial cell and the relative ages of other cells by observing the point at which each makes its appearance, these essential facts can be ascertained with a fair amount of accuracy in other ways.

No examples of *Favosites conicus* have been obtained which represent only the younger periods of growth. Specimens, as usually found, are unattached, but in each case on the under surface a group of cells occupying a central and apical position are broken. These cells represent the cementing portion of the corallum, broken when the latter was detached, and indicate the number and position of the primitive corallites.

This consideration, together with those above enumerated, afford a fairly accurate determination of the younger cells and their grouping about the initial cell.

The development of the corallum in this species seems to be essentially the same as that of *Favosites forbesi.* This is most apparent from figure 19, plate VIII. The initial cell produces four buds from the dorsal side, as the second generation, and ultimately becomes surrounded by individuals, which are not, presumably, sprung directly from itself. In figure 17 the normal number of buds belonging to the second generation is apparently increased to five, but the extra cell, that on the extreme left, is so small in the comparison with the others that it seems justifiable to refer it to the third series. In figure 18, on the contrary, the second generation seems to be one short of the usual number. A large but unbroken individual on the left may represent the missing cell.

Favosites hemisphericus.

The specimens here under discussion, from the the Corniferous limestone, are referred doubtfully to the species *F. hemisphericus.* Their small size precludes the possibility of comparing them definitively with the large coral masses which are classified largely on the form of the corallum. In this species the development in its early stages proves to be identical with *F. forbesi* (plate VIII, figure 16). The growth of the corallum has not been followed to the stage where the initial cell is inclosed.

OBSERVATIONS.

Perhaps the most noticeable features in the development of the corallum in *Favosites* is that the initial corallite gives rise to buds which are (*1*) four in number, and (*2*) all on one side (dorsal) of the corallite. Moreover, this tendency toward unilaterality is persistent and results in the fact that not until the fourth or fifth generation does the original individual attain an inscribed or subcentral position. Four species of *Favosites* have been discussed, all belonging to the globose or pyriform variety. They come, moreover, from four distinct horizons, yet the essential feature of their development appears to characterize the pyriform type of growth. The conclusion seems warranted that this feature remains constant throughout the genus in the hemispherical forms. The fol-

lowing explanation of these two elements (*1* and *2*) and their origin is suggested:

An initial corallite which gives off in succession six buds equally distributed around its perimeter is taken as an archetypal form. Then, following the mode of growth observed in *Favosites forbesi*, before the secondary corallites are large enough to bud, the divergence of these cells allows six interstitial buds in the six corners, thus decussating with the second generation.

In the third generation, the inherited tendency would be for the six members of the second generation each to produce six buds. The diagram (plate VIII, figure 21) represents the condition of the corallum at this period. It will be seen that, owing to the interstitial buds, one side of the corallite (*b*) is appressed to the corallum. As a result but four buds can be developed normally by each individual, the two others existing *in potentia* as pores, since pores and buds are fundamentally homologous. This process is repeated by each member of the corallum (except the initial cell) and at each act of gemmation. By accelerated heredity there would finally result an initial cell giving off four buds on one side of the polyp.

In the suppositious corallum above suggested, the initial cell was assumed to put forth six buds, constituting the second generation of the corallum. A little later six others are produced, alternating with the first series and forming the first set of interstitial cells. The third whorl of buds would be above the first, the fourth above the second and so on, forming in this way twelve vertical rows of buds or pores. This fact shows a striking and significant identity in number with the almost invariable number of septa, and therefore of intersepta [illegible] observed in *Favosites*. Moreover, in *F. forbesi* the initial corallite at the first generation gives off regularly [illegible], then three others alternating with these and so on. This development, however, is on one side only, and if [illegible] completely around the circle would give twelve [illegible] generation (see diagram 22, plate VIII). In this set of [illegible] the defense for choosing precisely six [illegible] rather than any other number.

[illegible] hexagonal form of the corallite rules

throughout the coralline is apparent, while the mechanical cause and geometric necessity are equally obvious. It may be that the hexagonal symmetry (in septa and buds) of the individual in a favositoid colony is due to the hexagonal form. together with the habit of prolific budding in the earlier stages, especially in the ancestral type suggested in this paper. The constitution of the corallum is such as to force the buds of each individual to fall into 6 or 6x vertical rows, and this in turn might affect the development of septa. On the other hand, it may be objected that for the same reason hexagonal symmetry must prevail in colonies of rugose corals, whereas tetrameral symmetry is found to be the rule. Among the *Rugosa*, however, budding is either calycinal, where the life of the parent is terminated by the act of gemmation, or, when lateral, is not usually prolific.

In *Favosites* one of the most noticeable features of the corallites is the mural pores, which extend in one or more vertical rows along each face, and, apparently, served to connect the visceral cavities of adjacent polyps. If a marginal row be observed it will be found to run parallel with the edge for a short distance, then, approaching it, to pass to the other side. There is usually an enlarged pore upon the angle from which a bud is produced, truncating in its growth the edge of the prism.* For a short distance, the original row remains solitary upon the new face, when suddenly one or more rows are initiated, apparently by the young bud. In other words, the pores extend upward in parallel series, in an irregular and extended spiral. The bend in the line of pores apparently indicates a slight twisting on the part of the corallites, which may be due to the tension of the bud in its effort to acquire an upright position. To this cause is very likely due the intermediate and alternating position of all the young cells. It would thus follow that the calcified and consequently immovable portion of the corallite did not extend as high as the hinge-point of the pore line when the bud was given off. It is not supposed that the spiral movement of the pores was produced by a continued and slow revolution of the corallite. The introduction of new series with new buds and the disap-

*Beecher, 1891. Trans. Conn. Acad., vol. VIII, p. 215, et. seq.

pearance of the old ones might give this impression, while the yielding due to tension may be only local.

The existence of rows of pores on all sides of each cell has no bearing on the question of the unilaterality of that cell, nor is the number of rows a key to the number of radii of gemmation. Any or all of the pores may be developed from adjacent corallites. It is not assumed, however, that buds are necessarily produced on but one side of each cell throughout the corallum, although no instances to the contrary have been observed. If a complete gemmation does occur in *Favosites*, it may be regarded as a reversional manifestation, and is to be looked for in senile or pathologic individuals.

How far the development observed in *Favosites forbesi* holds good for *Favosites* as a genus it is difficult to determine. It seems probable however, that in all the globose forms, the development is one-sided, and that the four cells, which may be termed the increment of generation, characterize the development of coralla of this form. Variety may occur in the order in which these cells are given off, and in the persistence with which they are reproduced. On the basis of their mode of growth, Favosite colonies may be roughly divided into dendroid, explanate, and globular or hemispherical forms.

The growth of the globular forms is essentially radial. The interstices which consequently arise are filled, as fast as they appear, by new buds, so that at any given point in its growth the corallum abounds in small, immature calices. It is conceivable, however, that the divergences might be so distributed that all the young cells matured simultaneously, before any new ones appeared, or even that this might occur periodically. In this form the number of peripheral buds is comparatively small, and after attaining a certain point, the corallum depends for its increase almost exclusively on interstitial germination. This point is reached at an early period, and is determined by the form of the object of support. When the peripheral cells rest on the surface, further increase by the introduction of new ones is clearly impossible except, perhaps, laterally between the old cells. In that case their character is uncertain and their number small.

With the incrusting forms, it is far different, as the growth of the corallum is peripheral and the introduction of inter-

stitial buds fortuitous. Instead of being divergent, the corallites here are parallel and contiguous.

In the branching varieties, however, the growth, as determined by mature specimens, is exclusively by interstitial germination. As can readily be seen, this, joined to a limitation in the length of each corallite, would produce a trunk-like corallum, the branching being effected by the outgrowth and prolongation of a number of corallites in a body. There is no permanent apical bud, but one assumes a central position for a time, and then swerves outward, terminating at the perimeter, while another takes its place. Possibly bifurcation of a stem may result from the deflection or divergence of two cells of nearly equal size, having a central position.

The hemispherical forms, therefore, seem, in their mode of growth, to stand midway between the explanate and the branching forms. These coralla have no proper limit of growth, and the size which they attain depends largely upon external physical conditions. As the dendroid shape seems to be a subsequent specialization of the pyriform variety, its earlier development would probably agree with *F. forbesi*, while both forms, the globose and the dendroid, pass through a more or less explanate stage. The explanate and arborescent varieties, however, have not been investigated by the writer in their earlier stages. The affinities of *Favosites* as determined by its mode of growth would seem to be with *Aulopora* and *Romingeria* rather than with any other genera of the *Perforata* excepting *Michelinia* and *Pleurodictyum*.

Like *Pleurodictyum*, *Favosites* passes through an auloporoid stage* represented by the initial cell. When one or two secondary cells have been added, the corallum can still be likened to two auloporoid cells, where, the stolon being reduced to a mere pore, the corallites themselves are brought into close apposition. Even a large favositoid colony can, in the same way, be compared with a colony of *Aulopora*, although in the latter, as far as known, so many as four cells are not budded from one individual. A further point of similarity is established by the fact, that, in both genera, the individual cells produce buds on one side only.

Nicholson and other writers have apparently ignored this

*First pointed out by Beecher (l. c.) in connection with *Pleurodictyum*.

relationship of *Aulopora*, although *Syringopora* is referred to the *Perforata*, and *Syringopora* likewise passes through an *Aulopora* stage in which the whole colony is prostrate and attached. On the other hand, although the genus *Aulopora* bears an outward resemblance to certain forms among the *Alcyonaria* with which group it has been customary to place it, the cell walls in such colonies are characteristically formed of consolidated spicules, while *Aulopora* shows no trace of such structure. *Aulopora* cannot strictly be called a perforate coral, unless the creeping stolons* are equivalent to the aërial stolons of *Syringopora*, which are homologous with pores. The corallites of *Aulopora* are seldom adjacent, but, when at rare intervals they are found in contact, this feature has not been investigated. As the corallum in *Favosites*, if spread laterally and distributed along a plane, can be likened to an auloporoid colony, so, if continued upward and loosely constructed, it would correspond to a romingerioid colony. This would be especially true of the primitive form assumed for *Favosites*, in which the buds are developed in a complete verticil. It may be that *Favosites* and *Romingeria* have a common ancestry, and that while the open construction of the corallum in the latter genus permitted the individuals to retain their symmetrical system of budding, *Favosites* assumed a compact mode of growth and became unilateral.

Yale University, New Haven, Conn., April 25, 1894.

EXPLANATION OF PLATES.

PLATE VII.

FIGURE 1. An initial corallite of *Favosites forbesi* which has not developed buds. Lateral aspect. ×4.

FIGURE 2. The same. View of the calyx. ×4.

FIGURE 3. *Favosites forbesi.* The youngest colony found, in which but two buds have been developed of the four which usually represent the second generation. ×4.

FIGURE 4. The other side of the above. ×4.

FIGURE 5. The same specimen seen from above, showing plan of the colony. ×4.

FIGURE 6. A specimen of *Favosites forbesi* attached to the genal spine

*The procumbent attitude of *Aulopora* seems to be directly associated with the diffuse structure of the colony in that genus. The stolons in *Syringopora* and the verticillate system of budding in *Romingeria* illustrate two modifications by which this type of structure is enabled to prolong and maintain its growth vertically.

of a trilobite. The specimen represents the completed second stage where no interstitial buds have been developed. ×4.

FIGURE 7. A corallum of *Favosites forbesi* attached to a ramose bryozoan. The colony, which consists of cells of the second and third series, is recumbent and no interstitial buds have been developed. ×4.

FIGURE 8. Another example of *Favosites forbesi* in which the four secondary corallites and some of the third generation have appeared without any interstitial cells. The oldest cell of the third series is in this case evidently older than the youngest cell of the second and its position is between b_1 and b_2, being probably developed from the former. ×4.

FIGURE 9. *Favosites forbesi.* A recumbent though detached colony, consisting of cells of the first, second, third and fourth generations. No interstitial buds have made their appearance. This feature appears to be characteristic of the recumbent forms, which, in the parallelism of the corallites and the absence of interstitial cells, bear a resemblance to colonies of the explanate type where these characteristics remain constant through life. ×4.

FIGURE 10. A nearly recumbent colony of *Favosites forbesi* which had grown attached to one valve of a *Meristina nitida*. The four cells of the second generation have been developed, together with two or three interstitial corallites. Enlarged after Hall.

FIGURE 11. *Favosites forbesi.* A specimen in which appear an unusually large number of interstitial buds. The number of secondary cells is normal. ×4.

FIGURE 12. An example of *Favosites forbesi* in which the initial cell and two of the secondary corallites are distinguishable. Many interstitial cells are present. ×4.

FIGURE 13. A young colony of *Favosites forbesi* in which the arrangement of the corallites is irregular. ×4.

FIGURE 14. A pathologic specimen of *Favosites forbesi.* The walls are thickened and one of the cells closed by an operculum. ×4.

FIGURE 15. Another example of the same, showing cells of the first, second, and third generations, and one central interstitial cell. ×4.

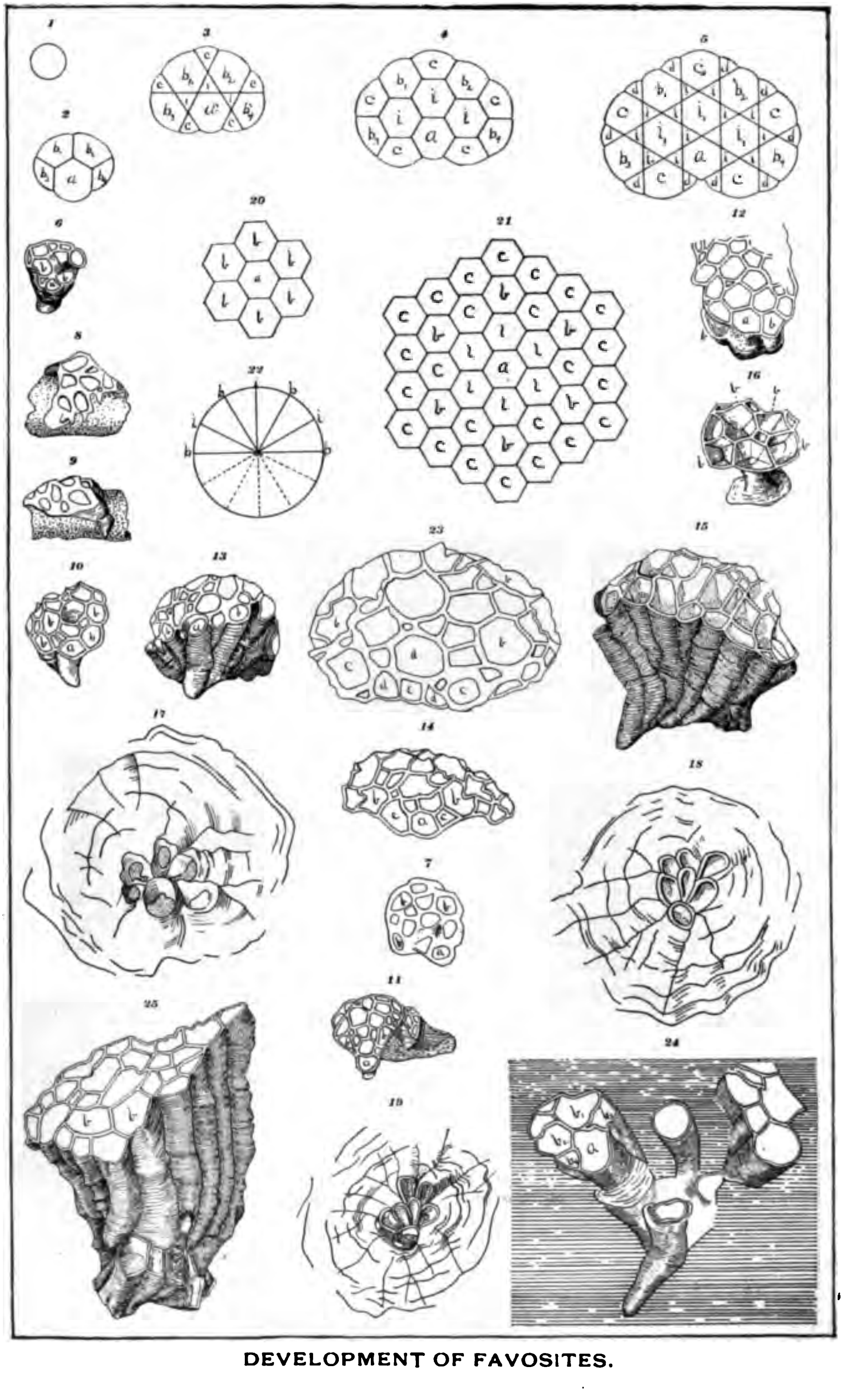
FIGURE 16. A specimen of *Favosites forbesi* which shows the systematic position of cells of the first, second, and third generations. ×4.

FIGURE 17. A specimen of *Favosites forbesi* which well illustrates the method of determining the relative ages of the constituent cells. The position of the corallites in this specimen is very symmetrical, but more than the regular number of cells belonging to the third series have appeared. There are no interstitial cells. The corallum was erect and attached only at the base. ×4.

FIGURE 18. Lateral view of the same.

FIGURE 19. Another view of the same. ×4.

FIGURE 20. A corallum of *Favosites forbesi* in which appear cells of the first, second, third, and fourth generations, together with a large number of irregularly disposed interstitial cells. The initial corallite still has a peripheral position. ×4.



DEVELOPMENT OF FAVOSITES.

FIGURE 21. Portion of the upper surface of a colony of *Favosites forbesi* which shows the initial cell surrounded by cells of the third and fourth generation. ×4.

FIGURE 22. A corallum of *Favosites forbesi* with corallites of the first, second, third, fourth, and fifth generation. The interstitial cells are numerous and irregular, the central one older than the others. The initial cell has here an inscribed position. ×4.

FIGURE 23. Part of the surface of another specimen of *Favosites forbesi* illustrating a period of development a little subsequent to the last. Cells of the first, second, third, fourth, and fifth series are represented, and these are in turn enclosed by another series of buds peripheral to themselves. ×4.

FIGURE 24. A curious intergrowth of two colonies of *Favosites forbesi* into a single corallum. The development of each is regular. ×4.

FIGURE 25. The same as seen from above. ×4.

FIGURE 26. An abnormal form of *Favosites forbesi* in which only three secondary cells have been developed. ×4.

PLATE VIII.

FIGURES 1, 2, 3, 4, 5. Diagrammatic representation of several stages in the development of *Favosites forbesi*.

FIGURE 6. *Favosites spinigerus*. The youngest specimen observed. The initial cell with the four secondary cells have been developed. There is a central interstitial bud as old as the second series. ×4.

FIGURE 7. A young example of *Favosites spinigerus* showing a large number of interstitial buds characteristic of the species. ×4.

FIGURE 8. A prostrate example of *Favosites spinigerus* with highly thickened walls. ×4.

FIGURE 9. Another view of the same. ×4.

FIGURE 10. A specimen of *Favosites spinigerus* showing the initial cell, the four secondary cells, and a large number of interstitial cells. ×4.

FIGURE 11. *Favosites spinigerus*. A large colony in which the initial cell occupies a peripheral position. This feature, the result of a lateral extension of subsequent cells, is characteristic of this species. ×4.

FIGURE 12. Another extensive colony of *Favosites spinigerus* where the initial cell is peripheral but not so prominent as in the preceding. ×4.

FIGURE 13. Another colony of the same species showing the lateral growth of the secondary corallites and later series. ×4.

FIGURE 14. *Favosites spinigerus*. A specimen showing the relative positions of the principal members of the second and third series, together with the initial cell still peripherally seated. ×4.

FIGURE 15. Lateral view of an extensive colony of *Favosites spinigerus* exhibiting the prominent position of the initial cell. ×4.

FIGURE 16. A specimen of *Favosites hemisphericus* which shows the initial [illegible] surrounded [illegible] cells, and the central interstitial [illegible] the [illegible] condition of this specimen [illegible] ×4.

FIGURE 17. [illegible] colony [illegible] figure represents part of the outer surface [illegible] the [illegible] corallites [illegible]

the rest and represent the attached portion of the corallum. The large and round cell is the initial corallite. Five cells abut upon it and are mutually distorted, while the initial cell retains its proper shape. The one on the extreme left is so much smaller than the others that it may be referred to the third series. ×4.

FIGURE 18. An example of the same species in which only three secondary corallites have been developed, or possibly where the fourth is considerably younger than the others. ×4.

FIGURE 19. A specimen of *Favosites conicus* in which the four buds of the second generation are strikingly shown. ×4.

FIGURE 20. A diagrammatic represention of a hypothetic initial cell (*a*) which produced symmetrically six secondary cells (*b*).

FIGURE 21. Diagrammatic plan of the same colony if six interstitial buds (*i*) were introduced in the angles between the initial and secondary cells, and if each secondary corallite (*b*) inherited the tendency to produce six buds of the third generation (*c*). Twenty-four such cells can be produced symmetrically by the six secondary corallites, with an average of four apiece.

FIGURE 22. A diagram showing the plan of the initial cell of *Favosites forbesi* to illustrate the radii of gemmation. The radii lettered (*b*) would produce the four secondary corallites together with interstitial cells of the second, fourth, sixth, etc. series. The radii lettered (*i*) would produce interstitial cells of the first, third, fifth, etc. series in an ideally perfect corallum. It is evident that a symmetrical development of this system would give twelve radii of gemmation.

FIGURE 23. A specimen of *Favosites forbesi* which shows cells of the first, second, third, fourth, and fifth series. The initial cell has an inscribed position. This colony is a very symmetrical one, but is distorted by being drawn in perspective. ×4.

FIGURE 24. *Favosites forbesi.* This specimen is partly concealed by matrix. A group of cells have become separated from the rest of the colony. The oldest individual of the group (*a*) appears to have produced from its dorsal side four other corallites (*b*) in the manner of initial cells.

FIGURE 25. A pathologic specimen of *Favosites forbesi.* The initial cell and several of the cells next produced were killed by some catastrophe to the colony when it was still young. Further development took place without the co-operation of those cells, and to this fact is probably due the wedge-shaped form of the colony. ×4.

EARLY PROTOZOA.

By G. F. MATTHEW, St. John, N. B., Canada.

Some months ago the writer received through the favor of Mr. L. Cayeux, of Paris, a paper describing certain radiolarians which had been discovered in the pre-Cambrian rocks of Brittany. This article has now been followed by a shorter

one describing Foraminifera from the same rocks; and the two form together a very important contribution to our knowledge of the pre-Cambrian faunas, which gradually begin to unfold themselves. The present seems a fitting time to give a brief outline of what is known of these ancient faunas and especially to review the work of Mr. Cayeux.

Since 1865, when Sir Wm. Dawson described to geologists the characters of Eozoon, a controversy as to the existence of pre-Cambrian animals has gone on, and many naturalists found it difficult to satisfy themselves of the organic origin of the object which provoked this controversy.

The cause of this skepticism is not far to look for; it is owing to the imperfect preservation of the characteristic structures of such ancient fossils. Mr. Cayeux has met with the same cold reception for his pre-Cambrian rhizopods; for while satisfied himself, he could not convince others, owing to the obscureness of the examples first studied. However, after arduously working for two years, he not only discovered many new forms, but found some so well preserved that their characteristics could not be gainsaid. Eozoon will in the same way win its way to general recognition; anyone who has been so fortunate as to find and study well-preserved "canals" of Eozoon will hardly dispute the organic origin of that form.

As we approach the base of the Cambrian the Protozoa become more marked as a constituent part of the faunas, perhaps because at the upper horizons they are masked by organisms of higher type and have not been so assiduously looked for. This at least would be the inference drawn from a glance through the lists of species of that age that have been presented to the scientific world. Thus Foraminifera, sponges and other Protozoa have been found a common constituent of the Ellipsocephalus (or Protolenus) fauna (below the Paradoxides fauna) in Acadia (eastern maritime provinces of Canada).*

Except sponge remains, no Protozoa are described from the Olenellus zone in the United States.

A variety of forms referable to the Protozoa are also to be

*See On Phosphate nodules from the Cambrian of Southern New Brunswick, by W. D. Matthew. Trans. N. York Academy of Sciences, vol. XII, Apr., 1893.

found in the shales of the Etcheminian series, some from a thousand feet below the Ellipsocephalus horizon, above referred to. The predominance of organisms of low organization thus appears to be a notable mark of faunas at the base of the Cambrian.

In giving a sketch of Mr. Cayeux's work on the Protozoa of the pre-Cambrian of Brittany, I take up first his later paper (June, 1894) describing the Foraminifera which he found with radiolarians (the latter being by far the most numerous) and which he says "originally had a calcareous shell."

This fauna was found in the siliceous rocks on the north of Brittany, known under the name of "phtanites" and placed at the border of the crystalline schists and the clay slates (or "schists") of Saint Lô.

Mode of occurrence of the Radiolarians and Foraminifera.

"Haüy has formed the name *phtanite* for siliceous *stratified* rocks, disposed in thin beds, frequently repeated and of great extent in the Cambrian and Silurian formations.* A certain number of the beds in Brittany are true phtanites, in the modern petrographical sense of the word; but the greater part present their silica entirely crystallized to the condition of quartz and should be classed as quartzite."

Dr. Charles Barrois, who first discovered traces of radiolarians in the rocks of Brittany, and placed them in the hands of Mr. Cayeux for study, has carefully worked out the geological horizon of the phtanites, and finds that they have given pebbles to the conglomerates at the base of the Cambrian and to those of the schists of Saint Lô, and, therefore, must be as low as the base of the latter. He has asserted that these schists are identical with the Uriconian of Caer Caradoc, and are non-metamorphic representatives of the Pebidian of St. David's in Wales. Dr. Barrois also has traced these phtanites and quartzites throughout Brittany, but has found their associations greatly changed in some parts, viz.:

1. They are contained in granulitic gneiss at Varmes.

2. In mica-schists and micaceous schists at Lorient, St Nazaire and Nantes.

*This term appears to correspond to the "chert," "siliceous slates," or siliceous mud rocks, of early English authors, perhaps the most siliceous of them.

3. In crystalline schists near Pornic.

Thus while they are in relation to the sedimentary rocks in the north of Brittany, they are subordinate to the crystalline schists in the south. "We understand the importance of these observations to those geologists who see in the crystalline schists the sedimentary rocks metamorphosed."

"As the term pre-Cambrian is applied as a definition to the mass of all the stratified sediments, anterior to the Cambrian, in a condition to contain organic remains, it is by preference to the pre-Cambrian period that I [L. Cayeux] refer them."

It will be seen that Mr. Cayeux's use of the term pre-Cambrian is relative and it is made equivalent to Huronian of the geologists of the Canadian survey, and Algonkian of those of the United States survey.

Description of the Foraminifera.

In his later paper, June, 1894, published in the transactions of the Geological Society of France,* Mr. Cayeux describes the Foraminifera of this fauna. These Foraminifera were simple or compound. He passes by the simple ones as capable of being confounded with certain radiolarians, the pores of which have been obliterated. The compound forms had chambers varying in number from two to seven. These chambers were either spherical or oval, and those of two or three chambers had a few short processes (rudiments of spines); the cells were not arranged in a single series, but so disposed that each might be tangential to two others. Mr. Cayeux observed that some individuals had their tests pierced with minute pores, which would refer them to the Foraminifera *Perforata* of Carpenter. "Like the pre-Cambrian radiolarians these have dimensions which separate them from the known palæozoic Foraminifera. The largest chambers scarcely attain a diameter of 10 μ."

"Whether isolated or agglomerated chambers be present it is possible to distinguish the fragments of Foraminifera from those of the radiolarians that accompany them, for with the latter there are vestiges of pores of large size. The mode of junction of the chambers with the multilocular forms is also a distinguishing feature."

The Foraminifera figured by Mr. Cayeux recall very forcibly

*Compte rendu de la Société géologique de France, p. 79.

the small globular bodies from the Eozoonal limestones of the Ottawa valley found by Sir J. W. Dawson and described under the name of Archæospherina.* Compare them also with those obtained from the Protolenus (or Ellipsocephalus) horizon of the Cambrian rocks at St. John, N. B., found by W. D. Matthew.†

Description of the Radiolarians.

"It was in June, 1892, that Dr. Barrois placed in my hands [Cayeux] sections of the phtanites and quartzites that he had collected in the neighborhood of Lamballe (Cotes-du-Nord) in which he had observed *circular sections*, recalling those of radiolarians. Though the circular form was there, the structure was not apparent. After a very minute examination I recognized some traces of hexagonal reticulate structure, favoring the hypothesis that the slides contained radiolarians; and not only so, but I thought I recognized very primitive forms belonging to the Monosphærida."

For two years M. Cayeux gave himself to the careful microscopic study of these phtanites and was able to confirm the first observations by the "discovery of a complete fauna of siliceous rhizopods, remarkable for the great number of individuals and of genera which it contains. The number of shells found has been very great," and he has published a plate of 45 forms of these pre-Cambrian radiolarians.

Mr. Cayeux would not publish his work until he had submitted the slides to those interested, including foreign learned specialists, who, though not agreeing with his conclusions, admitted that the forms were organic. Two of the persons specially referred to are Mr. G. J. Hinde, of London, and Mr. Rüst, of Hanover.

The difficulty of the investigation of fossil radiolarians may be inferred from the statement of the latter savant in his memoir on the Triassic and Palæozoic radiolarians, that he had made more than 5,000 thin microscopic sections to obtain 200 forms of radiolarians in a good state of preservation; and Mr. Cayeux declares that he himself was not much more fortunate—and he adds that one of his slides is of more interest

*Geol. Mag. London, vol. II, p. 334. Also "Life's Dawn on Earth," by J. W. Dawson, London, 1875, p. 137, fig. 33.

†On Phosphate Nodules from the Cambrian rocks of Southern New Brunswick. Trans. N. York Acad. Sci., April, 1893, p. 114, pl. 3.

than all the others united, as from it are drawn all the data for the plate published with his article.

The care he took to eliminate the "personal equation" may be inferred from his statement that he had a special artist employed, who had never drawn radiolarians, to draw the figures for the plate, and who figured "*just what he saw*" on the slide.

Mr. Cayeux remarks that there is an advantage in studying these radiolarians first with a low power, as thereby one can see their irregular distribution; they multiply in some places so as to touch each other, and in others they are represented by but few individuals. It was after using objectives of high power that Mr. Cayeux was able to resolve the apparently small spheres into a greater variety of shapes; he describes them under the following heads:

1. Radiolarians identical with known genera.

   Legion *Spumellaria*, Ehr.

   Cenosphæra several species, *Carposphæra*, *Xiphosphæra*, *Stauræsphæra*, *Acanthosphæra*. *Cenellipsis*, *Spongurus*,

   Legion *Nasselaria*, Haeck.

   Tripocalpis, *Tripodiscium*, *Archicorys*, *Cyrtocalpis*, *Dictyocephalus*, *Stethocapsa*, *Dicolocapsa*, *Theocampe*.

2. Radiolarians whose reference to known genera is uncertain.

   Some of the above genera and *Triactoma*, *Lithapium*, *Anthocyrtis*.

3. Forms undetermined, but which are certainly Radiolarians.

   All these are referable to the above legions, and to families of the genera above named.

After describing the forms, Mr. Cayeux mentions and refutes the various objections made to his reference of these fossils to the radiolarians. Among these objections is the claim that these spherules are too small to be referred to radiolarians, and that there is no visible reticulation of the test. It seems to the present writer that the small size of these objects is no bar to their being radiolarians, for such a relation of the primitive types to the fully developed forms is quite in keeping with the history of other organisms. Take, for example, some of the earlier Palæozoic trilobites: the initial

forms of the Paradoxides are only a tithe of the length of the giants of this fauna that appeared at a later time; compare, also, the earliest Dicellocephali with the later ones; the earliest asaphoid forms with Megalaspis or Isotelus; compare also the gigantic Terataspis figured by Prof. J. M. Clarke* with the earliest representative of its type. (*Terataspis grandis* Hall, Tenth Annual Report of the State Geologist, Albany, N. Y., 1890.)*

Character of the Pre-Cambrian Radiolarian fauna.

In noting the character of the fauna of these pre-Cambrian radiolarians, Mr. Cayeux observes that he found two groups "(legions)" known elsewhere and at a later time in a fossil state, and that these two groups form a notable part of the existing fauna of radiolarians.

Among the genera present, Cenosphæra predominates over all others. It is a genus that exists at the present day, and more than thirty species dwell in the ocean at the present time: and at all depths to 3,000 fathoms. Haeckel has made the genus to play an important part in the phylogeny of the radiolarians, making it the stock form of the sub-order Sphæroidea. Notwithstanding its great antiquity it is far from being the simplest of the radiolarians, being superior to all those without a skeleton, or with imperfectly trellised skeleton.

Alongside of Cenosphæra are other Sphæroidea more developed, representing some of the principal families of this sub-order. Several forms of radiolarians referable to higher orders are found, including the turreted forms of the Cyrtoidea and other Nassellaria. These occupy a high place in the classification of the radiolarians, have played an important part in the Tertiary ages, and multiply in the modern ocean.

One fact remarked upon by Mr. Cayeux is, that while these higher forms are present, they are comparatively scarce; but the spherical forms, and especially Cenosphæra, are so abundant as to form the principal bulk of the individuals observed.

In brief, "there co-existed in the pre-Cambrian simple radi-

---

*It will be seen that from this point of view the objection taken by a German writer to the small size of the meshes of a fragment of Cyathospongia found by the present writer in a Laurentian quartzite near St. John, will have no weight. We are naturally to look for the dwarfing of organic forms as we trace them to the earlier deposits.

olarians, numerous and composed of few genera (*Spumellaria*) and radiolarians much more elevated in organization, and less abundant, but distinguished by a greater number of specific forms (*Nassellaria*). Such is the salient character of the fauna."

"Notwithstanding the numerical superiority of Cenosphæra, that is to say, of the genus which counts among the most archaic of the group, this fauna of radiolarians, considered as a whole, cannot be regarded as the fauna of radiolarians which first appeared: it possesses a character of complexity and completeness, such as implies the preëxistence of several other faunas of radiolarians less developed."

"Such a fauna found at an epoch more recent would lead us certainly to the conclusion that it had been preceded in time by more imperfect radiolarians; why then should we reject the same conclusion when the pre-Cambrian is concerned?"

"We only deduce from the ancient faunas the supposition of faunas older yet. All our efforts to exhume the most primitive creatures end invariably in the same result—to push back the date of the appearance of life on our planet."

"It is to the study of siliceous micro-organisms that the geologist who desires to restore the first pages of our palæontological archives should apply himself. Experience has shown that the radiolarians have the quality of preserving the completeness of their form and their composition, despite the metamorphism which transforms all around them. So I believe [says Mr. Cayeux] that the last words on the most ancient faunas will appertain to the microscopists."

[CRUCIAL POINTS IN THE GEOLOGY OF THE LAKE SUPERIOR REGION. NO. I.]

THE STRATIGRAPHIC BASE OF THE TACONIC OR LOWER CAMBRIAN.

N. H. WINCHELL, Minneapolis, Minn.

It is proposed to re-examine, in the light of present developments, several of the points of greatest difficulty in the geology of the region of lake Superior. It is on these questions that geologists have differed. It is possible that there is less uncertainty, when the facts are all grouped in a systematic

manner, than at first appears. Two recent notable efforts have been made to put into harmony, on a broad basis of classification, the rather divergent views and interpretations of the lake Superior region. We refer to those of Messrs. Walcott and Van Hise, the former in a bulletin of the United States Geological Survey entitled "Correlation Papers, Cambrian," Bulletin No. 81, and the latter in a similar bulletin, entitled "Archean and Algonkian," Bulletin No. 86, the former published in 1891, and the latter in 1892. These masterly summaries of the literature of these subjects are a credit to the U. S. Geological Survey, and will long remain standards of comparison for future study. But, like all human undertakings, they exhibit the genius and the "personal equation" of their authors. This can hardly be considered a fault, for it is a characteristic which the greatest products of the greatest men always manifest. Indeed, the personal stamp of the author goes with every advance which is made in geology, as well as in all departments of human progress. Every new step must be based on a previous step. That earlier step is the foundation and the governing element, not only in the direction of the new step, but also very largely in the particular nature or quality which it exhibits. For this reason the various steps of any seeker after new truth can be interpreted by tracing backward the line through which the investigation was pursued. The steps are interpreters of each other.

It is therefore of the utmost importance that no *first step* be taken erroneously, or if erroneously, that it be retraced frankly and a new foundation laid in a step in the right direction, and of the right quality as to force and scope. It will be incumbent on the writer therefore, in the preparation of a series of papers on the geology of the lake Superior region, to enter somewhat into the history of the progress made already and to write what might be called a review of the two foregoing correlation papers. In the course of this examination it may appear that several false steps have been made by the authors which ought to have been retraced, but which were used as foundation stones for further advance, and that therefore they have arrived at faulty results.

With the early English geologists there was perhaps as much difference regarding the base of the Cambrian as re-

garding the summit. Murchison at first made the Llandeilo the bottom of his Lower Silurian,* and simply called the non-conformable underlying rocks "slaty grauwacke," without pushing his descriptions further downward. Later, however, by a series of unjustifiable enlargements of his Silurian system, he represented that all the old strata containing a trilobitic or brachiopodous fauna should be put in the Silurian. He thus made Barrande's "primordial zone" a part of the Silurian and theoretically covered all that is known of the faunas of the Cambrian. Even Sedgwick. in his final "Tabular view," omits the Longmynd slates from his Cambrian, although they had before been included with the remark that "their exact place in the general series is doubtful."† In another place he includes the Longmynd rocks, with some doubt, in the Skiddaw slate at the bottom of the Cambrian. It was only after the visit of Barrande to England in 1851, resulting in the announcement of fossils from the primordial zone in that country, that careful examinations involving the base of the Cambrian began to be made. A vast amount of labor and of literature has been devoted to the British Cambrian since that re-examination began. Various life-zones have been established and some definiteness in the parts has been reached. Some of the English geologists, under the lead of Dr. Hicks, to whose timely energy and skill is principally due the elucidation of the Cambrian faunas and stratigraphy in south Wales, are satisfied to limit the downward extension of the Cambrian at a series of conglomerates and grits which in some places seem to coincide with the base of the Olenellus zone; while others, who perhaps have with them the majority of the working geologists of Great Britain, include in the Cambrian those formations which Hicks has called Pebidian, Dimetian and Arvonian, which are very largely of eruptive characters. If these be embraced in the Cambrian, the bottom of the Cambrian in the British Isles is an unknown quantity. The Olenellus zone, even, has not yet been fully identified in Wales where the Cambrian was first studied. It is in Pembrokeshire specially that the base of the Cambrian is in

*London and Edinburgh Philosophical magazine, July, 1835, p. 46. Reprint in the AMERICAN GEOLOGIST, vol. v, p. 80, 1890.

†British Paleozoic fossils, p. iv, 2d Fasciculus.

a confused manner involved with masses of eruptive rocks, granites, felsytes and dolerytes, embracing marbles, schists, gneisses and basic eruptives.

It is apparent, therefore, that in Europe any stratigraphic plane which may be assumed for the base of the Cambrian would be wholly artificial; what would be the base at one place, owing to a progressive subsidence which, according to Dr. Hicks, has been found to have been in progress during the whole of Cambrian time, would not be the base in another. The Middle Cambrian (Menevian) lies on the Archean in the Anglesea area, and in several other places in Wales, the very base being conglomerates with a marked discordance on the crystalline schists. In Shropshire the lowest recognizable Cambrian strata carry Olenellus, and they lie upon a series of volcanic materials, made up both of lavas and fragmental ejections which have been classed as pre-Cambrian, though not on the best of evidence. Such volcanic products are found to underlie the Upper Cambrian in Warwickshire.* Dr. Hicks has supposed, from a survey of all these facts, that a subsidence of the continental areas, both eastern and western, brought the Cambrian sea further and further upon the land; that this was accompanied by such volcanic and other physical changes that not only was the fauna extinguished in the oceanic waters thus affected, but that volcanic ejections were from time to time interbedded in the Cambrian strata. Thus a kind of general similarity of lithology and succession of parts was imprinted on these strata on both sides of the Atlantic. It has been remarked by Sir Archibald Geikie that "the rocks of the Cambrian system present considerable uniformity of lithological character over the globe." Probably the progenitors of the Cambrian fauna lie buried under all the later strata in the basin of the Atlantic. The oscillating continental borders, the *loci* of the most frequent flexures of the crust and of the escape of molten rock from volcanic vents, would thus be re-peopled in periods of quiet by immigration of new species from the adjacent ocean,† thus making a rec-

*LAPWORTH, Geological Magazine, 1886, p. 321.

†HICKS, Quart. Jour. Geol. Soc., XXXI, p. 552. Natural Science, vol. V, Dec., 1894.

ord of progressive evolution, synchronous on both sides of the Atlantic.

With this brief reference to the condition of geological opinion as to the base of the Cambrian in Britain, we wish now to call attention to the condition of geological opinion as to the base of the Taconic system in America. We shall find a great similarity of fact and of progress in research.

That there was a long period of pre-Taconic time during which the older strata, whatever their origin and composition, were flexed and rendered holo-crystalline,is generally admitted. There is a marked change from this crystalline condition in which it is sometimes difficult to discover any remaining proof of sedimentation, to the clastic Taconic strata. This transition is marked also by a profound non-conformity, the wide extent of which has been recognized by several recent writers. It is not intended here to say that no clastic structures are found below this break, nor that no crystalline rocks are found above. In fact clastic structures are very apparent in those rocks older than this break, but in that case a metamorphic re-crystallization usually accompanies them; and everywhere without exception in America, so far as known, such clastic strata are so highly tilted that verticality is their normal position. It is a fact also that some of the Taconic strata have been affected by a similar metamorphism. It is found, however, that when thus disturbed the Taconic strata attain verticality only in exceptional cases and in small areas, while the massive crystallines which are found associated with the Taconic clastics are, as a class, of wholly different characters from those which preceded the great non-conformity. The presence of these characteristic crystalline masses in immediate proximity with the occasional sharp folding and metamorphism of the Taconic, serves, with other means which need not here be mentioned, for the distinguishing of the later strata from the older when they are both present in a region. While these broad distinctions can be drawn it must be admitted still, that they have not always been observed, and that there is, consequently, not a unanimity of opinion as to the age of the rocks at this horizon in various parts of the United States and Canada. That which we wish to particularly emphasize as an important fact in American

Paleozoic geology, is the profound structural change which here takes place, and the necessity of recognizing it as the base of the Taconic or Lower Cambrian sediments.

If we inquire, now, more closely as to the nature of the lower portion of the Taconic, we find everywhere, as already stated, a conglomerate at the base. This is true whether we examine the Cambrian's contact with the Archean near the horizon of the Olenellus zone, or near the horizon of the Upper Cambrian (Olenus zone of England). From this conglomerate upward the fragments become finer and finer, making a quartzyte. This is followed by a calcareous zone and iron ore, and these by black slates. All of these separate parts may be seen in contact on the Archean, in different places.

The unfortunate controversy which arose respecting the age of these rocks in America, while not exactly the parallel of that which sprang up in Britain between Murchison and Sedgwick over the limits of their respective "systems," has served to obscure the actual facts and to prejudice the cause of geological research on these most interesting formations. Facts which have entered into history, as to this controversy in America, need not be revived. But new men, and new issues have appeared on all sides, and, as in Britain, much more is known now than formerly, of the whole question. So many lights have been recently turned on these problems from different quarters that nearly all the old problems are solved, and the advancing research now has to do with many new problems of more direct and special import and more limited scope. Only so many of the results of past research will here be mentioned as seem to bear on the nature of the base of the Taconic.

The following arrangement of the main parts in descending order, seems to be the result of all the work on the Taconic strata in the original Taconic area:

1. A series of slates and schists, often black, but sometimes gray and siliceous: toward the south becoming roofing slates and even mica schists.

2. A greenish, soft, magnesian schist or slate, sometimes siliceous, becoming nacreous schist.

3. Limestone, passing to marble, associated with quartzyte and alternations of mica schist.

4. Quartzyte, with alternations of mica schist.

5. Conglomerate, firmly bedded upon the underlying gneiss, apparently changing to gneiss in some places.

These parts have all been found to contain the characteristic fossils of the Taconic or Lower Cambrian. Their age is no longer in question. The thickness of this series of strata is very great, reaching more than twenty thousand feet. Toward the south they become crystalline and have been considered, on lithological characters, as belonging to the Archean. They are all involved with the basic gabbros at Cortlandt, N. Y., and are converted into apparently massive eruptives, taking the various forms of dioryte, and quartzose granitoid rocks,* while at more remote points from the focus of igneous action the region is occupied by mica schists and gneisses, produced by a regional metamorphism of the same strata, as shown by Dana. The base of the Taconic, therefore, if the continuous areal tracing of these strata from Vermont to New York city by Prof. Dana was correct, is apt to be crystalline and has been invaded by gabbros and associated basic eruptives, at least in the region of eastern New York south from Albany. The iron ore belt which is closely connected with the main limestone stratum in the same region, is another noteworthy feature. Dr. Edward Hitchcock traced it out carefully in Vermont and represented it by a continuous color running into Massachusetts. Prof. Dana has followed it as far south as Dutchess county.

A similar crystalline series is found in the Adirondacks, intimately connected with the gabbros of that region. The Adirondacks are on the opposite side of the Hudson-Champlain valley and must be considered to have had a history in some broad respects identical with the history of the eastern side. The eruptives here followed the Taconic strata, as to date, and where they did not effect their fusion they rendered them crystalline over wide areas, producing a series quite different from the true Archean. Massive quartzytes and bedded gneisses are included in this later crystalline series, associated with marble, hematite iron ore, and conglomerates. In general the eruptive rocks not only are of the same kinds as those of the Cortlandt area, but they have the same relations to the concerned clastics. They have broken through

*G. H. Williams, Am. Jour. Sci., (3) xxxv, pp. 438-448, 1888.

and crystallized certain limestones, quartzytes and schists, often involving isolated masses and separating them from their parent strata.

There is in none of these cases, so far as known, any eruptive older series, or volcanic breccia, on which the basal quartzyte of the Taconic has been found to rest, but, whenever the basal contact on the older rocks has been found, the older rocks are gneissose or granitic. The igneous rocks at this horizon on the other hand seem to have been of some date later than the commencement of the Taconic, and either by general fracturing of the whole formation involved them in tumultuous confusion, or to have been interjected between their strata after the strata were formed. This statement is not intended to deny the existence of older igneous rocks, or even volcanic breccia, in the Archean, on which the Taconic may rest in other places, for it is well known that such exist and that the Taconic might lie on them. It might be truly said also, that so far as yet discovered the basal beds of the Taconic, when fragmental, have not been found in eastern New York and New England to consist of volcanic materials. That such may yet be discovered is quite evident, not only from the occurrence of such strata in the base of the Lower Cambrian in south Wales, but from the existence of such materials in great quantities in the midst of the strata of the Penokee range in Wisconsin, which are believed to be of the age of the Taconic, as will appear later.

Further south, in the region of the South mountain, one of the parts of the Alleghany mountains in Pennsylvania and Maryland, Mr. Walcott has reported the finding of the Olenellus fauna in certain quartzytes that are supposed to overlie volcanic rocks. The relations here are confused by faulting and folding,* and very different interpretations have been put on these rocks. To say the least, this position for these volcanics is not proven, the appearances indicating a very low place interstratified and intruded in the basal portions of the Taconic. As Dr. Williams remarks: "It may, however, be regarded as an open question whether the volcanic rocks represent a much older horizon * * * or whether they were

*C. D. Walcott and G. H. Williams, Am. Jour. Sci. (3) XLIV, pp. 469-496, 1892.

in part, at least, contemporaneous with the sandstones." A similar case is found in south Wales, where rocks identical in all respects with the South mountain rocks have for some years been classed as pre-Cambrian, having the names Pebidian, Dimetian and Arvonian applied to them, but which now are declared by Dr. Archibald Geikie to be intrusive within the Lower Cambrian.*

Further north, in the line of extension of the great Alleghany range, the Canadian geologists have met with similar rocks with identical associations. They are described by Messrs. Logan, Selwyn and by R. W. Ells, and are unhesitatingly put into the Taconic. Logan saw so many reasons for considering them comparatively recent that he assigned them to the old "Quebec group," which then was considered the northward extension of rocks, which in Vermont were called Taconic. The Canadian geologists are agreed on the question of the age of these volcanics, and compare them directly with the Keweenawan rocks of the lake Superior region.† In the Cambrian of Newfoundland the sections which are given by Murray show such rocks as diorites, porphyries and amygdaloids. These he puts, with their associated beds, into his "intermediate system," which he supposes is the parallel of the original Huronian as described by himself and Logan in the Canadian reports.‡

It is evident, from a survey of the facts from both sides of the Atlantic that the Taconic period was liable, from its commencement to its close, to widespread volcanic action, and its strata seem to manifest this fact in the constant intermingling of volcanic rock-material with the ordinary products of sedimentation. Where these events were most frequent the strata are less fossiliferous. Where they are not legible from the strata the sea was more fit for life, and in such places fossils have been found.

It is also apparent that the oldest sediments which may properly be included in the Taconic, above the great plane of

---

*Text-Book of Geology, 3d edition. 1893, p. 710.

†LOGAN Geology of Canada, 1863, pp. 241-244.
SELWYN. Rep. Prog. Can. Geol. Sur. 1877-78, A. pp. 3-15.
ELLS. Rep. Prog. Can. Geol. Sur., 1886, J, p. 28: 1887, K, p. 85.

‡MURRAY. Geol. Sur. Newfoundland, 1868, pp. 145-147. Republication of 1881.

non-conformity that separates the Taconic from the Archean have not been identified with certainty, and that whatever may be the horizon at which such contacts happen to be observed, they can be considered the base only for those several points of observation. That the conformable strata of the Taconic extend for many hundred feet, if not thousands of feet, below the zone with Olenellus is well authenticated in America. In Newfoundland, according to Mr. Howley, the present Government geologist, and in the opinion of Mr. Murray earlier, the Signal Hill quartzyte, and the underlying slates with *Aspidella* are not separable from the strata carrying Olenellus, though the Olenellus strata are much higher in the formation. Not including the Signal Hill beds, there is still a thickness of 1,800 feet below the Manuel's brook conglomerate containing Olenellus. In New Brunswick, according to Matthew, the Etcheminian series, reaching a thickness of 1,200 feet, lies below the St. John group proper, the base of which is thought to be at the Olenellus zone, and is hardly separable from the St. John group. Lately Mr. Walcott has reported the existence of a great thickness of conformable clastic strata below the Olenellus zone in the eastern slopes of the Appalachians, from Vermont to Alabama.*

If then we accept the great structural break which seems to be of wide extension in America, referred to above, as a datum from which to reckon the continuance of Taconic time, which would also be in accord with the views of Irving on the significance of non-conformities, the Taconic system would have a definite basal plane determined by the physical history of the earth, which has always been the governing element in the great faunal changes of geology.

THE SECOND LAKE ALGONQUIN.

By Frank Bursley Taylor, Fort Wayne, Ind.

(*Concluded.*)

The Attitude of the Deformed Plane. The remarkable uniformity of the main Nipissing plane does not appear to extend far toward the east from Sault Ste. Marie. For, as already stated, its projection in that direction passes about 40 feet below the Nipissing beach at North Bay. Its position seems

*Van Hise. Correlation Papers: Bull. 86, p. 169.

to suggest that the plane rises northeastward to an anticline or a fault. This, in turn, suggests that the inclination of the plane probably dies out toward the southwest somewhere beyond the node line and passes into a dead level; that is, into ground that was not affected by the change which produced the deformation. The attitude of the main plane is substantially such as it would be if it were the foot-plane of a simple northeastward uplift, and had been dragged up incidentally with a more sharply raised region lying farther to the northeast. Reasoning solely from the attitude of the main plane, the ratio of the northward component of elevation to the eastward component is about 19 to 8, or a little less than 5 to 2. But there are certain facts which show that the change was not so simple as this. If we examine Nipissing beach closely we find that its structure proves that for at least 25 feet from its upper level the water must have fallen away with extreme slowness and apparently at a perfectly uniform rate. This is shown at Au Train, Sand River, Marquette, and other places on the Superior shore, where the beach ridges of a numerous series are strong and very regular.* Spencer, as quoted above, reports much the same appearance on the shore of Georgian bay, and Lawson describes several such places on the north Superior shore. Considering the difference in the materials of the beaches, the case is almost as good at Mackinac and Gros Cap. These features exclude certain suppositions that might be made as to the character and order of the changes producing deformation. And among others they exclude the supposition of a simple northeastward uplift as given above. That idea seems fair enough at a glance, but it is based solely on a consideration of the attitude of the plane, without any reference to other evidences which may require a different explanation.

The Order of Changes. The order of events appears to have been about as follows: For a long period of time the upper lakes were in open connection with the ocean through several straits, the deepest being the one over Nipissing pass. This strait had a minimum width of 25 miles and a maximum depth of nearly 500 feet. Not until the waters had fallen away from this high level to that of the Nipissing pass, did

*Fourth paper, pp. 366-371.

lake Algonquin come into existence. There probably was some elevation at its outlet in the earlier days of lake Algonquin. But it is almost certain that there was none, or at least exceedingly little, in its closing days. For, as was pointed out above, an elevation of the outlet would cause all the shores of the lake to be submerged. The character of the beaches on the Superior shore, however, shows very clearly that no such change occurred during, nor for a long time after, the formation of the Nipissing beach and that at least in its later days the shores of lake Algonquin were not disturbed by any noticeable eastward deformation. But the Nipissing beach rises eastward and there is the old outlet to-day 160 feet above lake Huron and 40 feet above the main Nipissing plane. The only explanation which is entirely consonant with all the facts requires us to suppose that the eastward factor of deformation began at some time after the North Bay outlet, and the whole Nipissing beach, with all those for 25 feet or more below it, had been abandoned and left high and dry in consequence of simple northward differential elevation. And this northward elevation must have been very gradual and very uniform in its rate, if the present appearance of the Superior beaches goes for anything. On this line of evidence I am driven to conclude that it was not an eastward elevation that caused the change of outlet but a northward one. This points in turn to the more important conclusion that lake Algonquin, as defined by the Nipissing beach, was probably in a geological sense a very short-lived affair. For if there had been much northward differential elevation while the North Bay outlet was active and without causing it to go dry, the plane of lake Algonquin would have changed its attitude by swinging on an east-west axis through the outlet. The upper abandoned beach of Nipissing age north of that axis would then appear to rise northward more rapidly than that south of it. But no evidence of such a change of plane was found; on the contrary there is conclusive proof against it. For the main plane of the Nipissing beach passes right across the east-west axis apparently without the slightest sign of a break. This shows that the level of lake Algonquin from the beginning of the Nipissing beach must have been very close to the level of the St. Clair outlet: so close that only a very slight north-

ward elevation was required to cause the change of outlet.* From a consideration of the plane as above, we may argue that, since the Nipissing beach south of the North Bay axis was formed when both outlets were active at once, and since there is no extra rise of the plane north of that axis, it follows that all the lower beaches of lake Algonquin have been made since the St. Clair outlet opened. That being the case, it follows that very nearly all of the deformation which has affected the Nipissing plane must have taken place after the abandonment of the North Bay outlet. And further, since the last 40 feet of elevation at North Bay did not carry the water plane up with it, we may be sure that the St. Clair outlet was active at the time it occurred. These facts indicate that the level of the sea in the Mattawa and Ottawa valleys east of North Bay had probably fallen only a few feet below the level of lake Algonquin before the outlet was changed and the outflow at North Bay ceased. This agrees with the reported fact that the lower valley of the Mattawa shows no certain evidence of having been recently occupied by a great river.†

While these considerations do not locate the main eastward uplift exactly in time, the character of the beaches, however, seem to show that none occurred until after a simple northward rise of at least 25 or 30 feet had taken place on the south Superior shore. But there is good evidence to show that the simple northward rise was considerably more than this. The Pictured rocks, Grand and Au Train islands and the north end of Presque Isle are sheer cliffs, standing with their bases submerged. They show that no eastward component of elevation affected lake Superior until a considerable time after

*It is possible that a considerable part of the time of lake Algonquin passed before the time of the Nipissing beach. That period may have been closed by an uplift at North Bay raising the water in the whole basin to the level of the Nipissing beach which then began to be formed. But if there was such an uplift it was probably slight, and no certain evidence of it has yet been found.

†In his paper referred to above, Prof. Wright describes a great boulder terrace 80 feet above the river at Mattawa, and attributes it to the action of the old outlet river. It seems probable, however, that Dr. Bell is right in supposing this particular terrace to be morainic. It does not appear that the declivity of the Mattawa immediately above the village is sufficiently steep to account for such an accumulation as the result of river action.

that lake had become independent; that is, after the water had fallen from the Nipissing to, or a little below, the present Superior level at Sault Ste. Marie. For if that were the case, there would be a sharply accentuated beach passing westward from Sault Ste. Marie and sloping downward in that direction under the lake so as to pass about 25 feet below it at the Pictured rocks and Presque Isle, and the cutting of that shore would account for the present partly submerged cliffs. This probable significance of the cliffs of the south shore was long ago recognized by others. There are so many features of this kind on the south shore and about the western end of the lake, all pointing to a recent stage of the lake at a lower level, that the existence of this submerged beach seems certain. I propose to call it the Sault beach, for its place was determined by the barrier at Sault Ste. Marie. It was the last beach made by lake Superior before the beginning of the great eastward uplift and ought to appear above present lake level on all the Superior shore north of the isobase DD. The overhanging rocks, cliffs and caves of the Apostle islands show extreme littoral erosion, and this may be attributed to the fact that the present wave line strikes there a little above the same level that was so heavily cut by the waves of lake Algonquin. The

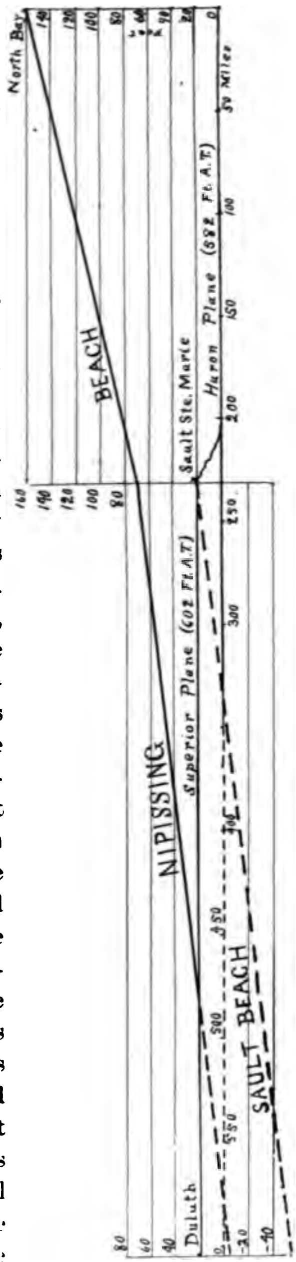


FIG. 1.

Palisades of the Minnesota shore are probably due to the same cause.*

The Nipissing beach is now submerged 25 feet at Duluth. But before the eastward uplift began lake Superior had become independent and its level had fallen 50 feet, or to the level of the Sault beach. It follows that when this last beach was formed the level of lake Superior at Duluth was relatively 75 feet lower than it is to-day. The submerged channel of the St. Louis river eroded 40 to 50 feet in glacial drift from Fond du Lac to the harbor of Duluth, and probably more or less refilled since, points strongly to a period of the lake at the supposed Sault beach level.†

Niagara and Lake Algonquin. But far away from lake Superior and the Sault there is another chronometer of the time since lake Algonquin lost its northern outlet. It is a part of the gorge of Niagara river. During the comparatively short life of lake Algonquin, and through all that much longer time while the sea filled the ancient Nipissing strait, the great cataract of to-day did not exist. During that time the channel of the Niagara river was occupied by a small stream which drained only lake Erie. The cataract of that stream was a small thing compared with that of to-day. Dr. Spencer has called this the Erigan river, and we may appropriately call its cataract the Erigan fall. Its volume was about the same as that of the present American fall, or about three-elevenths of the whole stream. The great difference in the magnitude of the Erigan and Niagara rivers leads one to expect that there would be at least some degree of difference of a corresponding kind between the gorges which their cataracts would make. And such a difference is there plainly enough. From the Horseshoe fall to a point a few rods above the cantilever railroad bridge there is a wide deep pool. The water in it is somewhat turbulent, but that is evidently not due to any feature of the pool itself so much as to the powerful currents that invade its depths from the foot of the present cataract. At the cantilever bridge, however, the gorge becomes perceptibly narrower and undoubtedly shallower, and the wild fury

*Lawson, op. cit., pages 197-8.

†Mr. Warren Upham, in Twenty-second Ann. Rept. Geol. and Nat. Hist. Survey of Minn., for 1893, Part III, p. 64.

of the water as it rushes toward the Whirlpool is plainly due entirely to the character of that part of the gorge. In short, the head of the old gorge of the Erigan river was a little above the cantilever bridge when the St. Clair outlet first opened, and it was there that the greater cataract of Niagara began its work. The distance from the falls to this point is a little less than two miles, and this represents the work of modern Niagara since it replaced the Erigan river. The facts seem to show that probably about half of this work was done during the progress of the simple northward uplift and before the great eastward elevation had begun.

In his recent admirable paper on the "Duration of Niagara Falls," Dr. Spencer has presented a more elaborate discussion of the development of the Niagara gorge than has ever been made before.* His cross-sections of the gorge are particularly instructive. With some slight omissions and additions I reproduce three of them here in fig. 2. It seems to me that there can be no mistaking section C, which represents the Erigan gorge, as the product of a much smaller stream than the greater Niagara which made sections D and E. This conclusion is still further strengthened when we take into account the obvious fact that the river in the Erigan gorge is much shallower than in the wider part above, probably not more than one-third as deep. But Prof. Spencer fails to offer what is, as it seems to me, the only true explanation of the Erigan gorge—the only explanation which is perfectly correlated with the lake history as revealed in the deserted beaches. He explains

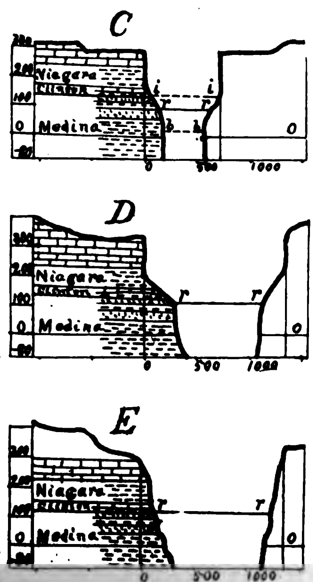


FIG. 2.

the Erigan gorge by supposing it to have been made by the great cataract at a time when there was a sheer fall of 420

*"Duration of Niagara Falls," by J. W. Spencer, Am. Jour. Sci., III, vol. XLVIII, Dec., 1894.

feet, and the greater hight of the fall is taken to account for the narrowness of the gorge. The depth of the river is assumed to be as great as in the parts above. A little consideration shows, however, that neither of these ideas is defensible on sound principles.

On the depth of the gorge of the rapids Dr. Spencer's conclusion seems to me to be contrary to conclusive facts. I regard it as a matter of simple demonstration that the river is much shallower there than in the wider gorge above the railroad bridges. If we know the volume of a river from measurement at some place where its velocity is moderate we may readily calculate its mean depth in any other place if we know its width and velocity. For its velocity is inversely proportional to the area of its cross section, and if we know the width and velocity then we can easily find the mean depth. I regret that I have no accurate data on this point. But after standing beside the rushing, roaring torrent of the narrow Whirlpool rapids and then being rowed in a skiff across the river at the American fall, one is fully convinced that the velocity of the water in the Whirlpool rapids can hardly be less than five or six times that in the wider gorge above. But according to Dr. Spencer's idea of a substantially uniform depth for the whole gorge, the water cross-section of the Erigan gorge is about half of that at Johnson's ridge. This allows for a velocity only twice as great. In order to find a cross-section to suit the observed velocity we must reduce the mean depth of the Erigan gorge to 75, 60, or perhaps only 50 feet. It is impossible to supply the conditions of high velocity for the rapids in any other way.

In support of the first point Dr. Spencer appeals to the law of erosion, viz., the steeper the declivity of a stream the more it cuts vertically and the less horizontal. This law is true for streams flowing without cataracts, but it does not apply to cataracts or vertical falls of different hights, and the exception is still more pronounced where the strata are horizontal and the weaker layers below are capped by a harder ledge above, as is the case with Niagara. The magnitude of the gorge in such a case depends mainly upon the stream's power of excavation at the bottom of the cataract where the water falls with greatest force upon the softer, lower rocks, under-

mining those above, and this depends, other things being equal, upon the hight of the fall. It is true that the higher the fall the greater its power to cut downward. But by the resistance of the rocks at the bottom and the consequent deflection

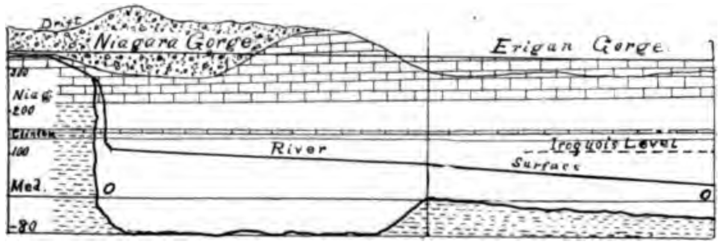


FIG. 3.

of forces in strong currents the power to cut laterally is also increased. For a cataract circumstanced like Niagara the law is the very reverse of that for rivers flowing without cataracts, namely, the volume of the river and the geological structure remaining the same, the higher the cataract the wider the gorge.

It is interesting to compare the gorge of the present period of Niagara with the channel of the rapids at Sault Ste. Marie. Since the abandonment of the Nipissing outlet, Niagara has cut back its gorge nearly two miles. But the Sault, which has probably been open half as long, has no visible recent rock gorge, or, if there is any, it is submerged. Of course there are many different elements to take into account. But even when a liberal allowance is made for all circumstances which might cause Niagara to cut back more rapidly and the Sault less rapidly, it still remains a fact that the difference between their amounts of cutting is so great that it demonstrates the younger age of the Sault. The inference from this fact should be put alongside of that drawn from the character of the Superior beaches. The beaches prove that the northward uplift was extremely gradual and even in its action, while the Sault without a gorge suggests that the barrier which holds up lake Superior was not uncovered until a considerable time after Niagara had replaced the Erigan river. But on the other hand, the submerged Sault beach in the Superior basin proves that the barrier had been uncovered some time before

the eastward uplift, and that until after its independence lake Superior was affected only by a northward element of deformation. The eastward uplift occurred, therefore, at a considerable time after the abandonment of the North Bay outlet.

By these facts relating to lake Superior and the Niagara gorge we are enabled to put the date of the eastward uplift, or rather of its beginning, at a considerable period of time after the extinction of lake Algonquin. The water must have fallen away from the Nipissing beach at Sault Ste. Marie more than 50 feet before lake Superior became independent. But a fall of 35 feet at North Bay closed the outlet, and it follows, therefore, that the closure took place before the Sault began its career. It is probable that the water at the Sault fell away even farther—more than 50 feet—before the beginning of the eastward uplift, because the submerged Sault beach necessarily required a considerable time to attain the pronounced development which the Pictured rocks and other products of its action show. In a word, the eastward uplift began only at a considerable time after the independence of lake Superior had been completed by the simple northward uplift. This is as far, however, as the order of changes can be made out at present on evidence which traces forward from the time of lake Algonquin. But over against this there are facts of another kind which enable us to put the beginning of the eastward uplift well back from the present time.

The St. Clair Flats. Not the least important of the many things that find an explanation in this study of lake Algonquin is that curious formation called the St. Clair flats. It is in reality a great modern delta of pure sand. But the waters of the St. Clair river, coming directly from lake Huron, are almost as clear as crystal. No other stream in that region, not even the muddy streams that empty into lake Erie, have any deltas, but all have open estuaries instead. Dr. Spencer, as quoted above, describes the heavy cutting of the waves along the present sandy shore of the east side of lake Huron. By their predominant run toward the south the waves are constantly carrying the sand in that direction, and the same is the case in a less degree on the west side. There is on this account a constant tendency for sand to collect at the south

end of the lake, just as it has actually collected in enormous quantities at the south end of lake Michigan. But the head of the St. Clair river opens just at the southern apex of lake Huron, and the result is that the drifting sand constantly passes into the river and tends to build out spits across its head. This process has actually contracted the entrance to one-half the average width of the river below. The spit on the east side is well developed and its point has been turned down stream by the current of the river. The predominance of drift from the east shore has crowded the river over against its west bluff and filled in the old channel for a mile and a half on the east side. This crowding process has made the rapids at the head of the river. As the sand is swept into the opening it is caught by the current which sets in strongly at the start (four and a half miles per hour) and is carried down stream. Once in the current the sand is kept rolling along the bottom until lake St. Clair is reached. Here the river strikes still water, spreads out, and slackens its flow. At this place, therefore, the sand comes to rest and the great delta of the clear river has gradually grown to immense proportions, and at a place about 25 miles from lake Huron. The delta has filled in nearly a quarter of lake St. Clair, and it covers nearly 130 square miles. The average thickness of that part of the delta which has been built since the beginning of the eastward uplift, supposing the level of the lake at that time to have been about 35 feet lower, must be 25 to 30 feet. It therefore probably contains not far from a cubic mile of sand, not counting submerged extensions, which would probably nearly double its area, but which are mostly thinner and would not add greatly to the whole mass.

It seems clear that the great eastward uplift did not occur until Niagara had consumed a large part, perhaps half, of the time which it has taken to cut the gorge back two miles. The rate of the recession of a cataract is liable to many irregularities. But if the rate for Niagara has been substantially uniform, then we might say that the St. Clair delta has been built in approximately the time that Niagara has been cutting back its last mile. Presumably the current of the St. Clair river was stronger in the past, before drowning by the eastward uplift had progressed so far as now. The power of

the river to carry sand therefore has probably been gradually decreasing as drowning progressed. The Nipissing plane projected southward to the mouth of St. Clair river, passes about 35 feet below its present level and below the bottom of the shallow lake. It follows that the delta above that level has been built since the eastward uplift began, and this implies a considerable lapse of time. It therefore puts the beginning of the eastward uplift relatively a long way back from the present day. But that is probably all it does. It reveals very little as to the present or very recent status of deformation, unless the one to three feet of water which now covers most of the delta may be taken to show a very recent drowning. As to the probable character of the most recent change, however, good evidence of another kind is close at hand. It was pointed out above that a northward differential elevation affecting the whole basin of the lakes as a rigid vessel would cause their plane to swing on an east-west axis passing through Port Huron. It follows that if there has been a very recent predominance of northward over eastward uplift, it ought to be recorded on the lake shores north of the Port Huron axis and south of the node line A A. The longest shore comprised between these lines is the west shore of lake Michigan. It is much the most favorable, and I have examined part of it closely. The appearance of that shore between Sheboygan and Two Rivers is described in the third paper of the above list. It shows no sign of a recently abandoned northward-rising beach, but affords instead positive evidence of present or very recent encroachment of the lake upon the land, showing apparently that the very latest phase of deformation has been eastward more than northward elevation, raising the outlet at Buffalo and consequently the level of all the waters west of it.*

At Mackinac and in the vicinity of the straits there is apparently an old water plane now submerged five to ten feet. It is seen in the wide submerged rock shelves and in numerous gravelly shoals in the adjacent parts of the lakes. But not enough is known of its character to be of much use in

*This fact may require a considerable modification of Dr. Andrews' estimate of postglacial time based on the erosion of this shore. (Quoted by various writers from the paper mentioned above.

this discussion. It is possible, however, that it is the correlative of the Sault beach in the Superior basin and indicates a partial resubmergence, which may include the region of Sault Ste. Marie.

This, then, is the history of the second lake Algonquin and of the subsequent deformation of its ancient water plane, so far as relates to the area which was actually occupied by the lake itself. There are, however, other outlying regions, which were surely affected by the same deformations. Some of these are near and others that were less certainly involved are far away. But a full discussion of the evidences from such regions would lengthen this paper unduly.

Evidence of Recent Elevation and Tilting in Contiguous Regions. Lake Erie, however, became so closely concerned with all the changes after the opening of the St. Clair outlet that it can hardly be omitted. It lies entirely on the lower side of the node line AA, and all its shores were therefore drowned when the eastward component of deformation began to act; and they were affected to a less degree in the same way by the northward component also. The Nipissing plane produced southward under lake Erie would pass about 60 feet beneath the present level at the mouth of the Detroit river and about 80 feet below Sandusky and Toledo on the south shore. But it may be that the plane decreases its declivity gradually southward and does not pass so deeply under as these figures suggest. All the rivers of lake Erie, including even the muddy, silt-bearing Maumee, are without deltas, and have open estuaries, many of which are navigable. It is undoubtedly the recent drowning of its shores that has made these harbors. Before that change took place, the Maumee must have had a fall of considerable hight over the rock ledges above Maumee City. The recent backing up of the water is plainly shown by many spits and bars, like the points of Maumee bay, Sandusky and Erie, and those at Pointe Pelée, Rondeau and Long point on the Canadian shore. Upwards of a thousand square miles of the former lower valley of the Maumee were submerged by the eastward uplift.

The deepest place in lake St. Clair is 30 to 35 feet at the extreme lower end of the lake, almost within the head of the Detroit river. The mean depth of the St. Clair river is about

30 feet, and it is the same for the Detroit river, except where it spreads out between islands and becomes somewhat shallower. There is one point in each river which is nine fathoms or 54 feet deep, and for considerable distances the depth is seven to eight fathoms. The soundings in lake St Clair show that the bottom slopes off gradually southwestward from the front of the delta to three or four fathoms and seems to show no submerged channels except near the outlet. It appears from these figures that the lake is shallower than the river above and below it, except at one point near the head of the Detroit river, and that there are parts of each river that are 25 feet deeper than the deepest point in the lake. But with so much sand passing through the St. Clair river, there must have been a considerable tendency to fill up the bed of the river itself. No doubt some filling has actually taken place. But it has probably been mainly by the coarser sand particles which were able te resist the current that swept the finer grains along to the delta. The delta has dammed the stream to a small extent and so deadened the current slightly.

Although it passes through only one plane of observation, the line EE has been put upon the map to show where that isobase would be, supposing the deformation at that distance to preserve a parallel relation to the other lines. It is not to be supposed, however, that the rise, or its acceleration, necessarily passes on indefinitely toward the northeast. It must come somewhere either to a fault or an anticline. A projection of the isobases towards the southeast beyond the limits of the map shows that lake Ontario lies full in the track of the main Nipissing plane, and also that EE passes right across the crest of the barrier which holds the lake up to its present level at Ogdensburg. Ontario's shores show many evidences of a recent change of the same kind which has drowned lake Erie. Along the south shore there are many drowned bays with recent spits and low bars, built across their entrances. Such are the Sodus bays, the Irondequoit and Braddock bays, and several estuaries along the shore west of Rochester. More of the same kind and very striking in their appearance are crossed by the Grand Trunk railroad in Canada between Niagara Falls and Hamilton. The great spit of Burlington bay

is very conspicuous at the latter place. The beautiful bay of Quinte is the drowned lower portion of the valley of the Trent river. Between Mexico bay and Drowned island on the eastern shore there are more bays like those near Rochester. Weller bay and East and West lakes, on the Pictou peninsula, are of the same kind. The St. Lawrence river above Ogdensburg shows plainly the effects of a recent drowning. The lands of that region, like those of the Erie basin, have recently been tilted upward at the northeast so as to raise the water in the upper St. Lawrence and in lake Ontario.

While there is at present no direct proof that all the late uplift affecting lake Ontario and the St. Lawrence was so recent as the eastward deformation of the Nipissing plane, still there are many facts which point to a large and very recent uplift of the whole Champlain-Ottawa-St. Lawrence-Hudson bay area. I cannot dwell upon these facts here. But if the degree of deformation recorded at North Bay is actually carried to the St. Lawrence, then it would account for more than 160 out of the 247 feet which marks the elevation of lake Ontario above the sea. In this connection the fact should not be overlooked that the amount of deformation which is found within the area of the four upper lakes is only relative. The total amount of uplift measured from present sea level is not disclosed by this discussion. There are many suggestive facts, however, which bear upon this important question. In a word, the conclusion which they suggest is that the Pleistocene uplift, which has so recently raised the marine fossiliferous beds of the Champlain submergence, was the same movement that produced the eastward uplift and deformation of the Nipissing plane in the upper lake basins. It may be appropriately called the Champlain uplift.

Summary and Conclusions.

When the outlet of the three upper Great lakes was shifted from North Bay to Port Huron, lake Erie was taken into the combination and since then has been affected by all changes in substantially the same way as the other lakes. So far, then, as relates to the history of lake Algonquin, and of the four upper lakes since the extinction of lake Algonquin, the successive steps and stages may be summed up as follows:

1. Widespread marine submergence prevailing at high levels in the north, producing a strait over the Nipissing pass 25 miles wide and 500 feet deep and attaining a mean hight of about 1,150 feet above the sea in the basin of lake Superior. Another strait passed at the same time over lake Tamagaming northeastward from lake Huron, and probably two others opened northward from lake Superior over the Hight of Land to Hudson bay.

2. On the rise of the land from the marine waters, Nipissing strait was the last to close and hence became the outlet of lake Algonquin, which was brought into existence by this change.

3. From the first, or at least from the time of the formation of the Nipissing beach, the level of lake Algonquin was very close to that of the St. Clair outlet, so that only a very slight uplift at the north shifted the outlet from North Bay to Port Huron, without making any apparent break in the plane across the North Bay east-west axis. The sea in the Ottawa valley had probably fallen only a few feet below the level of the North Bay outlet before this change took place.

4. It was a very gradual and simple northward differential elevation which shifted the outlet, and for a considerable time after that the areas of the four upper lakes were affected only by a progressive continuance of the same elevation. During this change the level of the lakes swung on an east-west axis through Port Huron.

5. Later, the uplift at the northeast introduced an eastward element of deformation and tilted up the Nipissing beach of lake Algonquin, so that it now rises 165 feet from Duluth to North Bay, and its direction of greatest rise at Mackinac is about N. 27° E. This uplift began long after the abandonment of the North Bay outlet and of the whole of the Nipissing beach north of the Port Huron axis, and also after the independence of lake Superior had been attained by the simple northward rise.

6. (a) The heavy and very regular beaches of Nipissing and later age on the south Superior shore show that the water in lake Superior fell away from the Nipissing stage with extreme slowness and regularity. (b) The cliffs of the same shore standing partly submerged mark the level of the Sault beach and show that the water fell for a vertical space of 50

feet or more, before the eastward uplift took place. (c) The absence of a rock gorge at Sault Ste. Marie shows that the rapids at that place are a comparatively new feature. These several conclusions taken together put the date of the eastward uplift a considerable time after the extinction of lake Algonquin.

7. For a long period prior to the change of the outlet, the channel of Niagara river was occupied by the comparatively small Erigan river which drained only lake Erie. This stream cut the gorge of the rapids below the cantilever bridge. When the St. Clair outlet opened, the greater cataract of Niagara began at a point a few rods above the cantilever bridge and since that time has cut back without interruption to its present place.

8. When the eastward uplift began, it raised the outlet of lake Erie at Buffalo and drowned that lake and also the south end of lake Huron, with the St. Clair and Detroit rivers and lake St. Clair. The simple northward elevation had previously produced a change of this kind on the shores of lake Erie, but in only a slight degree. The former change brought about the building of the upper 25 or 30 feet of the St. Clair delta.

9. The absence of a recently abandoned, northwardly rising beach on the west shore of lake Michigan, between the node line and the Port Huron axis, points to an eastward rather than a northward uplift as being the latest phase of change.

10. Many suggestive facts point to a correlation of the eastward uplift which deformed the Nipissing plane with the elevation of the northeastern barrier of lake Ontario and of the deposits of the Champlain submergence in the Champlain, lower St. Lawrence, and Hudson bay areas.

From the study of lake Algonquin and the earth-movements which have deformed its water plane, we are led to a few other obvious conclusions of a wider sort. Geologically, the lake itself was a very recent thing. But the great Champlain uplift which introduced the eastward element of deformation was still more recent. When we reflect on the great magnitude of the earth changes involved, both in their amount and areal extent, their recentness in time becomes more and more impressive as a lesson in the possibilities of late geologic his-

tory. The cause of these great changes is at present veiled in obscurity. Above the level of the Nipissing beach there are other complex series of shore lines. In the south they are undoubtedly referable to ice-dammed lakes of the glacial recession. But those of the south are not connected with those of the north, and in the north, where they are highest, there is no evidence of any relation to an ice-dam. For lake Algonquin in particular there is not the slightest indication of any relation to an ice-sheet, and there is no possible ground or excuse for such a supposition. All their stages and deformations are more plausibly accounted for in other ways.

Much yet remains to be done, especially in the way of systematic exploration, before the complete postglacial history of the Great lakes can be written. But this sketch of the history of lake Algonquin is offered as a small and necessarily imperfect contribution to the study of the recent history of the Great lakes, and in general, of Pleistocene changes of land attitude in eastern North America.

Explanation of Figures.

Fig. 1. Diagram showing relations of the Nipissing and Sault beaches to each other and to the Superior and Huron planes. In the vertical scale the Huron plane is taken as zero. The Sault beach is confined entirely to the Superior basin, and marks the last beach made by lake Superior before the great eastward or Champlain uplift which tilted the Nipissing plane.

Fig. 2. (After Spencer, modified.) Cross-sections of Niagara gorge: C, gorge of Whirlpool rapids, just below the railroad bridges; D, at Johnson's ridge, about a mile above the bridge; and E, at Horseshoe fall. At the top, in the Niagara limestone, section C is about half the width of D or E. Section C was made by the Erigan fall. The Iroquois beach (135 feet above lake Ontario at Lewiston) was made by the sea at the same time, and *ii* represents its level as the water stood in the Erigan gorge; *b b*, probable rock bottom of Erigan gorge, represented as 75 feet below present surface of rapids; *r r*, the present river surface.

Fig. 3. (After Spencer, modified.) This figure is intended to show the probable longitudinal section of the gorge from the Horseshoe fall to a point a little below the Whirlpool. It shows the Erigan gorge shallow and with bottom inclined. The depth of water at the foot of the Erigan fall is to be measured from the Iroquois level, and was therefore probably about two-thirds as deep as the present pool at the falls.

EDITORIAL COMMENT.

GLACIAL GEOLOGY OF GREAT BRITAIN AND IRELAND.

Subsequent to our too short notice of the posthumous volume by Prof. Henry Carvill Lewis, bearing this title, as given in the AMERICAN GEOLOGIST for last October (page 253), we have received from Prof. Percy F. Kendall, editor of the *Glacialists' Magazine*, the following more full notes and estimates of this very important work. Prof. Kendall writes:

Many causes conspired to defer the publication of this work until geologists in America and Europe had begun to despair of its ever seeing the light. The delay has not been an unmixed evil, for though many of the observations made and the conclusions arrived at originally by the late Prof. Carvill Lewis have in their publication been anticipated by other workers, yet scientific opinion in England is now far better prepared to accord them a sympathetic reception than it would have been had they, as was intended, been given to the world within a year or so of his lamented death. In no other branch of geological enquiry has the growth of opinion been so rapid as in that regarding the causes and conditions of the glaciation of the British Isles.

When, after a hasty survey of the British glacial phenomena, Agassiz and Buckland made an emphatic pronouncement in favor of the view that land ice on a vast scale had operated to produce the effects they noted, geologists soon ranged themselves in two sharply antagonistic camps. Whereas some accepted in their entirety the new views, others, comprising the older and perhaps more cautious reasoners, still adhered to the time-honored catastrophic doctrine of "great waves of translation." Opinion for a long time oscillated between these two extremes, but by degrees an apparent position of rest was found in the suggestion of some impartial observers who, recognizing, on the one hand, the irrefragable testimony of striated surfaces, the evidence of persistent carriage in one direction of erratics, and the existence of well defined moraines, and, on the other, the equally incontestable occurrence of marine shells in drift deposits at high altitudes, accepted the glacial hypothesis as an explanation of the former set of phenomena, while for the latter they accounted by a great submergence of the land. This view, in course of time, completely supplanted the older theory of great waves of translation, upon which so much mathematical skill was brought to bear, and it came to be regarded as one of the articles of the creed of scientific orthodoxy.

After Croll published his luminous elaboration of the eccentricity theory of the cause of the Ice age, evidence of interglacial epochs was sought far and wide. The occurrence of beds of sand or gravel in the drift was accepted as *ipso facto* proof of a warm epoch, and the existence of shells in them was regarded as additional evidence. To this idea, however, though all unwittingly, Croll himself gave the first blow by

proving that the fragmentary shells found in the boulder-clay of Caithness were merely the comminuted relics of shell-beds of the North sea, dragged in upon the land by glacier ice. Belt seized upon this discovery and applied it in explanation of the origin of the high-level sand beds of North Wales (Moel Tryfaen), which he considered might well be ascribed to the action of water near the edge of a glacier. This view was strongly reinforced by Tiddeman and Goodchild in their epoch-making papers on the glacial phenomena of North Lancashire and the Vale of Eden.

A fierce controversy ensued, centering chiefly around Belt's papers. So great, however, was the weight of authority arrayed against their daring author, and so strong was the tendency to measure all glacial action by the millimeter scale of the existing Alpine glaciers, that not all Belt's polemical skill nor his great field-experience (by a recent writer strangely minimized) could avail to secure him more than a half contemptuous hearing. With the disappearance of this bold pioneer ceased the unequal contest which he had initiated, and for a dozen years or more hardly a voice was raised in favor of his views.

Eventually Prof. Carvill Lewis, fresh from his work upon the great terminal moraine in Pennsylvania and the adjacent states, visited Britain with the intention of studying the effects of an ice-sheet upon a country similar in orographic form to Greenland. Ireland he conceived to furnish the nearest parallel, and he at once set to work and obtained, by a series of traverses, a good general idea of its glacial phenomena. In the course of this work he found what he considered to be evidence of a great terminal moraine marking the extreme limits of the ice-sheet. Finally he turned his attention to the sister island. His results were announced to the British association at its meetings at Aberdeen, Birmingham, and Manchester, in 1885, 1886, and 1887. In these communications, albeit they were, as his editor says, "to some extent 'trial papers,'" he sounded no uncertain note upon the vexed question of the "great submergence." At the same time he expounded views of great, nay, entire, novelty, regarding the demarcation by great terminal moraines of the limits of a series of huge glaciers whose courses he traced in England and Wales. He also recognized a system of extra-morainic lakes of great size, in which he thought the whole of the low-level drift of England south of the Trent and the Humber to have been deposited.

These opinions took English geologists completely by surprise. Notwithstanding that the winning graciousness of Lewis' manner, his eloquence, perfect mastery of detail, and wealth of illustration, made the exposition of his views one of the richest treats of the sectional discussions, he yet failed to entirely convince his hearers. The late Dr. H. W. Crosskey, who was secretary of the Erratic Blocks Committee of the British Association, met him with fact pitted against fact; but it must be said that Lewis showed himself as adroit in defence as in attack.

During the summer of 1888, Lewis returned to England full of large schemes of work, but bringing with him the seeds of that malady to

which in a few days after his arrival he succumbed. All his manuscripts and field notes, in accordance with his dying request, were placed in the hands of his generous adversary, Dr. Crosskey, who undertook the onerous task of editing them. How well he performed this friendly office will be seen by a perusal of the sixty-seven pages of introduction which he contributed to the work before us.

To fit himself for his undertaking, Dr. Crosskey visited the wonderful series of drift sections displayed during its construction in the course of the Manchester ship canal, and with the assistance of some local geologists made a careful scrutiny of such as seemed likely to throw light upon Lewis' work and his great deductions, with the striking result that in one important particular he became a complete convert to Lewis' views. On page lii he says:

"Moreover many of the beds, although not all, within the 100 to 150 feet level, which contain marine shells, Prof. Lewis attributed to the action of a great glacier which filled up the sea—as, for example, the Irish Channel—and, travelling onwards, tore up the sea bottom in its passage and distributed the material so derived over the land. A remarkable proof that Professor Lewis was right in this account of the origin of at least *some* of the shell-bearing boulder clays found at low levels has been given by the excavations recently made for the purpose of constructing the ship canal between Manchester and Liverpool. A series of boulder clays and sands has been brought to light, in which the boulder clay resting immediately on the basement rock contains both (1) material derived from the rock beneath it; (2) material from the sea bottom; and (3) material brought from distant mountains. Fragments of local rock have been torn off and imbedded in the boulder clay resting upon it. The basement boulder clay, as well as the superimposed boulder clays and sands, contains marine shells in a more or less broken and fragmentary condition. . . . . . At the same time there are extraordinarily clear proofs that the ice (to which alone it is possible to assign the formation of these boulder clays) was in motion and pressed onwards from the northwest towards the southeast. . . . . . I have examined the ship canal sections, and can come to no other conclusion than that the boulder clays, and at least a part of the sands, are the results of the *movement* of a great glacier which came down from the northwest into the Irish sea, carried the débris it there accumulated over the plains of Lancashire and Cheshire, and mixed it with locally derived material. . . . . . That *a glacier has certainly acted upon the surface of the local rock* appears to me proved. The boundaries and the depth of the glacier, not its existence, are, I think, the questions left for determination. . . . . The many questions which are involved in the various theories concerning the elevation and depression of the land cannot *all*, however, be solved by the fact that fossiliferous boulder clays and sands can be and have been formed by glaciers advancing from the sea."

This extract will show the generous and truly scientific spirit in which the editor discharged his duty. But it was not granted him to

see the work through the press: for a sudden and unexpected recurrence of a painful disorder, from which he was supposed to be thoroughly convalescent, brought his career to a close.

Of this work it would be difficult to speak in terms of praise too high. The papers, put together from fragmentary manuscripts, are clear and forcible expositions of Lewis's observations and conclusions. They are liberally illustrated by a series of beautiful maps. Lewis had a remarkable habit of giving to his field-notes the form of a continuous narrative, instead of that of a mere congeries of brief jottings, rarely intelligible to a second person, such as contents most geologists. The section of the book in which they are recorded is therefore equal in value to the papers themselves. The notes are full of minutely accurate observations, with a running commentary of shrewd inferences. They are moreover interspersed with extensive references to the glacial bibliography, often admirably abstracted, of each district examined; so that they will provide, through years to come, guidance both in the field and the study, for those who seek to follow Lewis' steps.

There are points whereon the present writer feels constrained to express dissent from Prof. Lewis' conclusions. He states, for instance, that Wharfedale in Yorkshire was not glaciated in its lower part, a conclusion difficult to reconcile with the existence of the great planed and glaciated surfaces which he himself saw. His ascription, too, of the formation of the great chalky boulder clay to the action of shore ice in a great extra-morainic lake seems clearly negatived both by the character of the deposit and by the absence of any high ground limiting the lake to the southward. The recent discovery there of an astonishingly large erratic of chalk, at least *one mile in length*, situated many miles from the nearest outcrop of the parent rock, is a fact which seems to point most clearly to the action of land- (glacier-) ice on a vast scale.

The limits of space forbid a more detailed discussion of the many merits of this remarkable book. Suffice it to say that the tendency, manifested in England since Lewis' death, to regard with favor his attempt to establish a parity between the glacial phenomena of the British Islands and those of North America, will receive a powerful impulse from this work. P. F. K.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

On new forms of marine Algæ from the Trenton limestone, with observations on Buthograptus laxus Hall. R. P. WHITFIELD. (Bul. Am. Mus. Nat. Hist., vol. VI. pp. 351-358, pl. XI.) This is one of the most interesting and important articles on fossil algæ which have appeared in a long time. As the author says, there have been so many forms described as algæ which may be worm burrows, tracks, trails or markings due to inorganic causes, that the finding of fossil algæ in so old a formation as the

Trenton limestone, showing unmistakable evidence of organization, is a matter of great interest and importance.

In his remarks upon *Buthograptus laxus*, regarded by Hall and others as a graptolite, Prof. Whitfield mentions the absence of any cells on the stipes or branches, and points out the peculiar articulation of the pinnules to the stems. The mode of growth is similar to that of the modern genus *Caulerpa*, but from this it differs in having the pinnules articulated to the stipe by a club-shaped base, instead of their being simply ramifications of the central stipe. He objects to the use of the name *Buthograptus* and believes *Buthorlaotus* would be a better term.

Two new genera and three new species are described. All but one are from the Trenton of Wisconsin, and this one occurs in the Trenton of New York. One of the forms was long ago noticed by Hall under the name of *Oldhamia fruticosa*. It is so obviously distinct from *Oldhamia*, however, that it requires little argument to remove it from this genus, and accordingly Prof. Whitfield has proposed for it the name of *Callithamnopsis fruticosa* (Hall). For a second species associated with the first and referred by Hall to his *Oldhamia fruticosa*, Prof. Whitfield proposes the name *Chætomorpha ? prima*. It does not seem at all likely that the modern, living genus *Chætomorpha* dates back to the Trenton, and Prof. Whitfield would, perhaps, have done better in proposing a new name like *Chætomorphoides*, for example. For while it may be *like Chætomorpha*, it is less likely to be the same genus.

For the third and fourth species the new generic and specific names of *Chætocladus plumula* and *Primicorallina trentonensis* are proposed. The first of these is associated with those previously mentioned in Wisconsin; the second occurs in New York. This last species is very interesting in its structure and reminds one by its general habit and mode of growth of the modern fresh-water alga *Batrachospermum gelatinosum*. In this species both the primary and secondary branches or pinnules are more numerous than in the fossil, but the mode of growth in the two is sufficiently similar to make a comparison justifiable.

We are glad to see at last some fossil forms from this older formation which all can refer to as algæ without querying whether or not they may be of inorganic or of animal origin. J. F. J.

From the Greeks to Darwin.—An Outline of the Development of the Evolution Idea. By HENRY FAIRFIELD OSBORN, Sc. D., De Costa Professor of Biology in Columbia College. Macmillan & Co. This work of 259 pages is divided into six chapters with the following titles: I. The Anticipation and Interpretation of Nature; II. Among the Greeks; III. The Theologians and Natural Philosophers; IV. The Evolutionists of the Eighteenth Century; V. From Lamarck to St. Hilaire; VI. Darwin.

The author early states that much of the evolution idea, which is generally thought to be modern, is in reality very ancient, and that its development has been gradual. The doctrine originated in Greece where it succeeded the old mythology. The first teachers were Thales and Anaximander. The former declared that water is the material from

which all life arose and out of which it exists. Anaximander (611-547 B. C.) regarded the earth as having first existed in a fluid condition, and from its solidification all living creatures, beginning with men, appeared. He was the first to teach the doctrine of abiogenesis. His pupil, Anaximenes, thought that plants and animals were produced from terrestrial slime through the agency of the sun's heat. Empedocles (495-435 B. C.) made a great advance over his predecessors. To him belongs the credit of having made the first observations on embryology. The four elements, fire, water, earth, and air, combined with love and hate, occupied a prominent place in his theories. From the budding of plants, came animals; though the latter did not at first appear as complete beings, but in parts,--shoulders without arms, heads without necks, etc. When love triumphed over hate, the parts began to unite, but in a wholly accidental manner. Thus appeared monstrous forms,--animals with the heads of men and the reverse. These monsters being unable to reproduce soon disappeared, and were succeeded by more natural forms. In these crude views appears the germ of the doctrine of the survival of the fittest. He did not believe, however, that the less perfect were succeeded by the more perfect, but that the less perfect were replaced by the more perfect. Anaxagoras (500-428 B. C.) used for the first time the doctrine of intelligent design in explaining the origin of organisms.

The appearance of Aristotle (384-322) marked another great advance in the evolution idea. His home being on the sea shore, his opportunities for observation were good, and consequently he early noticed the gradations between animals and plants. "He was the first to conceive of a genetic series, and his conception of a single chain of evolution from the polyps to man was never fully replaced until the beginning of this century." Like his predecessors, he believed in the spontaneous generation of organisms. He believed in the inheritance of acquired characters, understood the principle of compensation of growth, detected the differences between organic and inorganic beings and between animals and plants. Higher forms, he claimed, were produced from lower ones through an internal perfecting principle. It is astonishing to find him, twenty-two centuries ago, stating but rejecting the doctrine of the survival of the fittest.

With the death of Aristotle came a rapid decline in the study of philosophy. His doctrines were later taken up by the Arabs and carried into Spain; but the doctrines were placed under the ban of the church early in the thirteenth century, and hence the further study of Aristotle in Europe was checked.

With the awakening of science the natural philosophers again came to the front. Bacon (1561-1626) was perhaps the first to raise the question of the mutability of species. Descartes, a contemporary of Bacon, expressed the opinion that the universe is a mechanism which could be explained on a physical basis. Leibnitz in part revived Aristotle, and directed investigation to the gradations between species. The celebrated German philosopher, Kant, traced back all higher forms of life to simple organisms; referred to man's former quadrupedal attitude; ap-

preciated the effects of environment, accidental variation, and artificial selection. Oken, for reasons stated, is ranked much lower by Osborn than he has been by Haeckel. His philosophy is a curious mingling of science and myths.

Among the evolutionists of the eighteenth century, Buffon is accorded a high place. Yet his views varied greatly at different periods of his career. First he was a special creationist, then an extreme transmutationist, and finally concluded that species are neither fixed nor mutable. Perhaps his greatest service lay in his suggestiveness. Erasmus Darwin (1731-1802) believed in the spontaneous origin of the lowest forms of life. Yet he was a thorough evolutionist. The modifications of form, he thought, arose from reactions within the organism,—thus he anticipated Lamarck. He believed in the inheritance of acquired characters and made it a factor in evolution. The author gives an interesting sketch of Lamarck whom he pronounces "the founder of the complete modern school of descent and the most prominent figure between Aristotle and Darwin." He also takes up the parallelism between the writings of E. Darwin and Lamarck, and exonerates the latter from the charge of borrowing. Perhaps a criticism may be made here that Lamarck's views are not brought into sufficient relief, though they are stated at some length. The final chapter is devoted to Darwin and his contemporaries.

The work will be of great service to the general reader as well as to the men of science. It should be widely read. J. A. B.

A Preliminary Report on the Geology of South Dakota. By J. E. TODD. State Geologist. (South Dakota Geol. Sur., Bulletin No. 1, viii and 172 pp., 5 plates and a geological map of the state, 1895.) This is the first report issued by the recently inaugurated survey. It gives a detailed account of the present state of knowledge concerning the geology of the state, and as such will form a convenient starting point for further investigations. The Pre-Cambrian of South Dakota consists of (1) the granitic rocks of the eastern edge of the state, (2) the Sioux quartzite in the southeastern corner of the state, and (3) the slates, schists and granites of the nucleus of the Black hills. The Paleozoic strata are not extensively developed, occurring only in the Black hills. The Mesozoic rocks are the most extensive in thickness (with perhaps the exception of the Pre-Cambrian) and area, and of these the Colorado and Laramie divisions of the Cretaceous cover half of the state. Tertiary and Quaternary deposits are well represented, the Miocene covering a large area on the central southern side of the state, while the drift is confined to the eastern half of the state. After the discussion of the stratified rocks a chapter is devoted to the eruptive rocks, and one to a sketch of the geological history of South Dakota. The report closes with an account of the economic geology. C. S. G.

A Summary of Progress in Mineralogy and Petrography in 1894. Petrography and Mineralogy, by W. S. BAYLEY. Mineralogy by W. H. HOBBS. From the Amer. Nat. Price 50 cents.) The monthly notes on miner

alogy and petrography in the American Naturalist for 1894 have been reprinted and bound together in pamphlet form. An index of authors and a partial index of subjects have been added, and the whole makes a convenient and useful summary of progress in these two lines.

U. S. G.

Report of the Geological Survey of Ohio, Vol. VII. By EDWARD ORTON, State Geologist. Roy. oct., pp. xvi + 700; plans and figures, 56 plates of fossils, and a case of ten maps showing the outcrop boundaries of the principal coal seams. The volume is divided into four main parts, viz: Economic geology, Archeology, Botany and Paleontology. There is also a general chapter by Prof. Orton, explaining the whole geological scale and structure of the state, and another by the same, on the clays of Ohio, their origin, composition and varieties. A very full chapter is on the clay-working industries of Ohio, by Edward Orton, Jr. The coal fields are also described in a summary manner by the state geologist. Gerard Fowke discusses in a very intelligent manner the archeology of Ohio. He concludes the account of the mound-builders by the following statement: "Any statement, drawing or description of remains which attempts to show they were a race superior to, or different from all other natives of the United States, is not justified by any evidence so far discovered." The botanical chapter is by Prof. W. A. Kellerman and Wm. C. Werner. This also gives the bibliography of the botanical literature of the state. Some contributions to the paleontology of Ohio are given by R. P. Whitfield, reprinted from the Annals of the New York Academy of Science, 1880. Prof. C. L. Herrick reviews the "Waverly group." Aug. F. Foerste describes fossils from the Clinton group. Fossil fishes are discussed by Prof. E. W. Claypole, and Prof. A. A. Wright adds a supplement, the substance of both of which has appeared already in the AMERICAN GEOLOGIST. New Lower Silurian lamellibranchs are described by E. O. Ulrich, being an extension and supplement to work on the same published by him for the Minnesota survey. The book contains a large amount of valuable material, and constitutes a worthy finale of the report of the Ohio survey.

This volume completes the series begun with the survey of Dr. J. S. Newberry in 1869. It is perhaps to be regretted that the work is thus formally closed. Dr. Orton enumerates many important economic and scientific interests which yet need the attention of an official geologist. The educational interests of the state have a certain demand which they might make upon the legislature, and the state university might appropriately continue the survey along certain lines. In Alabama and Louisiana, as well as in Minnesota and South Dakota, the state survey is a function of the geological department of the state university.

Dr. Orton's connection with the Ohio survey has been long and often burdensome, and there is no doubt that he feels great satisfaction and relief in seeing it finally and formally terminated. But few state geologists have had the good fortune to close their surveys with such a completion.

N. H. W.

CORRESPONDENCE.

THE UPS AND DOWNS OF LONG ISLAND. The late Elias Lewis, Jr., of Brooklyn, some years ago published a paper in the American Journal of Science with the above title. The *ups* and *downs*, however, rather referred to the oscillations of our little island, than to the *Highs* and *Lowes* as they would say in Scotland. Professor Agassiz in a letter to Sir Charles Lyell, in referring to the coral reefs of Florida, says: "There are several concentric reefs separated by deep channels: the peninsula itself is a succession of such reefs, the Everglades being the filled in channels, while the hummocks were formerly little intervening islands, like the mangrove islands in the present channel." Professor Agassiz was the first, I believe, to notice these phenomena connected with the Florida reefs, and I was much interested in reading this account of them as published in his "Life and Correspondence," as I had begun to discover similar phenomena in the make-up of Long Island. Starting with the sea-beaches along the Atlantic border, we have, behind them, the bays with their deep channels and reef-like islands. The island itself is a succession of ridges and valleys, the beds of old rivers corresponding to the everglades of Florida, while the little kames and hummocks in these depressions were formerly little islands like those we see in Jamaica bay. Of course, these *ups* and *downs* of Long Island are not the same in origin as the Florida reefs, yet the similarity between them is very striking, and both exhibit system and orderly arrangement, showing that even the drift formations are not the fortuitous and disorderly things some have supposed.

At first there would seem no connection nor relationship between the moraines on the north side of the island and the line of beaches fringing the ocean, but I think it can be shown that the streams of water that assisted in forming one gave birth to the other. That is, it seems evident that powerful subglacial currents flowing from the main land plowed out the bay indentations on the north side of the island and gave form at least to the kame-moraines that constitute the most prominent range of hills on the island. It is characteristic of these morainic ridges to diminish toward the south, and the material composing them becomes finer in the same ratio. The streams that broke through the first moraine, and were confluent, generally converged south of this ridge, forming what is now a plain-valley: but they did not end here, but continued to branch off to the southeast and southwest. In their ramifications the hillocks were formed already referred to. These streams also penetrated what is known as the backbone of Long Island --the terminal moraine, of geologists—in the same ramifying way: and although these old channels are not so easily traced, yet the lines of drainage can be recognized along the kettle-hole depressions, and as they issue from the front of the moraine—I cannot say from the front of the ice-sheet, for I am inclined to believe that the surface part at least, of the glacier, extended farther southward—the same system of ramification was continued, and these old channels can now be traced

through the frontal plain to the bays, where a meeting of the waters again took place and resulted in the formation of the bays themselves. At least they gave them their contour, and the intervening islands, as already intimated, are the same in origin as the hillocks in the old abandoned river channels and depressions to the north.

Jamaica, Great South and other bay depressions on the south side of the island, show the effect of glacial streams upon them, and in places, where the flow of water was great, the detritus has filled in these bay depressions altogether, or nearly so, as at Far Rockaway, where a narrow strip of land divides Jamaica and the Great South bays, for here the floods broke through with great force from Flushing bay on the north. The points along the Great South bay are more or less conspicuous, according to the size and force of the old glacial currents. At Brookhaven, where there is still quite a stream running through the terminal moraine from the north side of the island, it will be found, that a point of land nearly separates the Great South from what is known as the East bay. At West Hampton, again, the bay only exists as a marshy depression, and the other Hamptons, to the east, come down to the ocean with scarcely a bay between; the same conditions prevail, however, throughout the whole extent of the island. Although beyond Amagansett the south side, with its bay depressions, has been swallowed up by the sea, yet, as if to complete and confirm this wonderful history of these glacial floods, a long arm of the terminal moraine is stretched out separating Amagansett and Napeague, making the Montauk division almost an island in itself, as the low marshy depression leading from Gardiner's bay to the ocean represents one of the old glacial river channels.

These points, along the southern bays, were formed very much the same way as the necks along the bay indentations on the north side of the island. Of course, the latter has a mantle of till, which the former has not, except in a slight degree, for the glacier is supposed to have ended with the southern ridge. There is evidence, however, that the surface part of the ice-sheet extended for some distance beyond the so-called terminal moraine. Some of the lower stratified deposits of clays, sands and gravels, on both sides of the island, may be preglacial, but it is evident that the turbulent streams of the great Ice age are in the main responsible for the *ups* and *downs* here treated of.

The bays, on the south, represent the last of the downs as far as they can be traced. The last *up* is the line of beaches along the Atlantic border. Those beaches have always been considered marine in origin, and no doubt they have been greatly modified by wind and wave in postglacial times; yet, I am very confident that their original formation was due to glacial currents, the same that swept the north side of the island and formed the kame ridges and deltas. It is hardly reasonable to suppose that such powerful currents terminated in the southern bays, and, in fact, there is good evidence that another *down* existed south of the present shore line, although the ocean bottom in front of Long Island is said

to be comparatively level,* as large fragments of turf are often washed up on the beach after a storm. Some of these *downs* have become submerged by the waters of the ocean in very recent times, as stumps of trees are found standing some distance out to sea, in what was once known as "Deecker's Meadow," near the west end of Long Island. As the sea gains on the land, the bays become part of the ocean, the marshes become bays, and the swamplands marshes; thus a submergence can take place without any oscillation of the shore. If Rockaway and the Great South beach should be washed away, and this is rapidly taking place, of course the whole of the southern bays would become part of the ocean without any sinking of the land, and it would not be long before the waves of the sea would dash up against the terminal moraine. This has taken place already along the Montauk division of the island.

Mr. Lewis, already referred to, and others have seen in the phenomena here treated of, proof of repeated oscillations, previous and subsequent to the Ice period. I am inclined to think, however, that most of the problems connected with the *ups* and *downs* of Long Island can be solved without resorting to this method of explanation.

Everything goes to show that the island remains very much the same as it came from the hand of the glacier, and this view is sustained by nearly all the leading geologists of to-day. There is still some dispute as to the instruments used in carving out the surface contour of the island. Dr. Merrill and some others contend that the bay indentations on the north side of the island were plowed out by projection spurs of ice and that the ridges along their margins are the result of lateral thrust. Years of careful study by the writer have led to different conclusions, and in this he is sustained by professor James D. Dana, both having arrived at the same results by independent investigation. I could see what professor Dana aptly described when he says that these bay depressions are too complex in form to admit of Dr. Merrill's theory; that is, these old channels ramify in such a way as to preclude the idea of their having been plowed out by lobes of ice; and, while the kame-moraines along the sound show some signs of pressure in the lower clay beds, as at Oyster bay, yet most of the stratified material gives evidence of having been deposited by currents of water *during* the melting of the ice-sheet.

In the study of these phenomena we are to remember that the glacial streams advanced with the glacier from the main land and that many of their connections have been broken off and lost in the waters of the sound. At the "Stepping Stones," however, near the entrance to the sound, there are a number of little islands existing, the equivalent of those referred to as occurring in the southern bays, showing the direction of the currents during the glacial floods. The bay depressions on both sides of the island represent only *detached portions* of the old glacial river system I have tried to describe, and this will explain why the present mouths of most of the rivers entering these bays are out of pro-

*See American Journal of Science, vol. XLI, p. 489.

portion to the size of the streams. This is due to the meeting of the waters in glacial times. This fact has presented an insolvable problem to some, for, if I remember correctly, professor Shaler was unable to explain this phenomenon in his report to the government on the marsh lands along the Atlantic coast. Take, for instance, the Setuck river at Eastport; three branches meet together where it enters the bay, and even the main stream is reinforced by another tributary that enters it above the railroad bridge, and where a large swamp once existed. The water has been dammed up and forms a beautiful lakelet at this point. The other branches were likewise augmented by lesser streams during the glacial floods, and where they all came together of course a larger depression was the result. It is interesting to note also that a line of kame ridges exists along the northern margin of the bays where these converging and diverging currents had their ramifications. The Montauk division of the Long Island railroad cuts through quite a prominent one at the Manor Junction, about half a mile west of the Eastport station. Here the Little Setuck has its rise, but the old channel, now dried up, can be seen a little farther north, where it is crossed by the Manor branch of the railroad. These old river channels can still be traced to the front of the moraine about two miles distant, but they ramify in such a way that no single channel can be defined, perhaps, from the bay to the ridge. That is to say, the old glacial rivers on issuing from the front of the terminal moraine divide and subdivide in such a way that their individuality becomes lost, but they have left their impress so plainly on the face of the island that he who runs may read, if he is not entirely blind to the wonderful works of nature.

Many of the ideas here presented have been suggested in previous papers in this magazine, but have never been fully formulated. I have endeavored to give here the facts, as they appear to me, after more than twenty years of study, and although the presentation is rather imperfect, I hope it may incite others, more competent, to examine the *ups* and *downs* of Long Island along the same line of thought. It is surely a subject worthy of attention, and if the views here presented are verified they will establish, I think, the unity of the Glacial period as far as Long Island is concerned. If our story of these *ups* and *downs* be true, it will show that all the morainic ridges are the same as to time and origin, and not the result of two separate and distinct ice-sheets. I may say, in closing, that the difference as to the modification of the two moraines is due to the fact that the glacial streams after breaking through the northern series of hills, were less successful in their onslaught on the southern ridge, for the reason that their forces had become more divided; there are few places in the terminal moraine as it is called, where the currents swept through to the plain beyond; therefore, as before stated, the old river channels can only be traced along the lines of kettle-hole depression; and along such lines the moraine is more or less modified, but not so much as the northern series of hills where the floods of water were more powerful. H. Carvill Lewis would have

designated the latter "kame-moraines," and I think this is a better name than "moraines of recession," as only the upper unmodified part of these hills was deposited while the glacier was retreating. On this point, however, there is much light still needed; and in fact the whole drift phenomena present difficulties that seem insuperable, though we are getting nearer the truth every day. JOHN BRYSON.

Eastport, L. I., N. Y., Dec. 7th, 1894.

THE NAME OF THE COPPER-BEARING ROCKS OF LAKE SUPERIOR. It is well known that the terms Keweenawan and Nipigon have been applied rather indiscriminately by different geologists to the copper-bearing rocks of lake Superior, and that these terms, as now generally used, are practically synonymous. On consulting the literature of the subject it was seen that there is good reason for retaining the term Keweenawan; and the following statement of the case is given with the hope that it may lead toward more uniformity in the designation applied to the rocks of this age in the lake Superior region.

The name Keweenaw seems to have been first applied to these rocks by Dr. T. Sterry Hunt in a paper read before the American Institute of Mining Engineers, Feb. 20, 1873. Here also he proposed the term Animikie. He says:

"The silver deposits of Thunder Bay and its vicinity, including Silver Islet, are in veins traversing a series of dark colored argillites and sandstones, which are as yet known only in this region, and are overlaid in slight discordance by red and white sandstones, apparently the same with those of the Keweenaw district and the St. Mary's river. This older series of Thunder Bay and its vicinity, *which may be named the Animikie group*, from the Indian name of the bay, is the lower division of the upper copper-bearing series of Logan.

"*The great Keweenaw group*, with its cupriferous amygdaloids, is here absent, though met with a few miles to the eastward, and the almost horizontal dark colored sediments of the Animikie group rest directly upon the edges of the crystalline Huronian schists, and are cut by great dykes of diorite."*

It is not clear that Hunt used the term *Keweenaw group* earlier than this, although it is not here spoken of as defined or proposed, but is used (apparently) as if it were a well known term. And he later speaks of "the overlying cupriferous conglomerates and trappean rocks *which we have named the Keweenian series.*"†

Dr. Robert Bell, in a paper read before the Montreal Natural History Society, Feb. 24, 1873, proposed the name *Nipigon* for the Upper Copper-Bearing series of lake Superior. This was reported by J. F. W. (perhaps J. F. Whiteaves) in the Montreal Gazette, and this report was published afterward in the Canadian Naturalist,‡ although the substance

*Trans. Amer. Inst. Min. Eng., vol. I, p. 339, published in 1873 or 1874. This paper was also published in the Engineering and Mining Journal, vol. XV, No. 9, 4th series, March 4th, 1873, pp. 129-132. The above quotation is on p. 131. The italics in this and the following quotations are the writer's.

†Second Geol. Survey of [illegible] "Azoic Rocks, Pt. I," p. 240, 1878.

‡New series, vol. VII, [illegible]

of Bell's paper had already been published.* The rocks included in Logan's Upper Copper-Bearing series were what are now known as the Animikie and the Keweenawan, with possibly the more recent sandstones of Sault Ste. Marie.† Bell says:

"If it were found desirable to give a shorter name to the rocks of the upper copper-bearing series of Lake Superior, I would suggest that of *Nipigon*. These rocks, as shewn on Sir W. E. Logan's geological map of Canada, form a broad band along the northwest side of lake Superior, running all the way from Thunder Bay to Duluth, at the western extremity of the lake. Within our territory their north-western limit runs inland in a general southwestern course from the north shore of Thunder Bay to Gun-flint lake."‡

In 1876 Maj. T. B. Brooks proposed the name Keweenawian:

"We are justified, I think, in regarding the copper-bearing rocks of Lake Superior as a distinct and independent series, marking a definite geological period which separates the Silurian from the Huronian ages. Should future observations confirm this view it would be advisable to have some more convenient and geologically acceptable name for the series than that now in use. Since Keweenaw Peninsula forms one of the most striking geographical features in Lake Superior and is the locality where the Copper series are best exposed and were first studied, I suggest the name Keweenawian for this period."§

Hunt proposed the term Animikie and used the term Keweenaw before a scientific assembly four days earlier than Bell proposed the term Nipigon before a similar assembly. Moreover Hunt used the term Keweenaw to refer to the copper-bearing rocks of Keweenaw point and their equivalents (i. e., to the upper division of the Upper Copper-Bearing series of Logan), although later his ideas as to the stratigraphic position of these rocks were erroneous;‖ while Bell's term Nipigon was proposed to include both the lower (Animikie) and the upper division (Keweenawan) of the Upper Copper-Bearing series. After the publication of the term Nipigon, Hunt suggested that, as there was some question as to the age of the horizontal sandstones east of Thunder bay, it might be used as a local name to designate these horizontal sandstones, but he distinctly states that, in his opinion, these sandstones are not to be confounded with those interstratified with the Keweenawan.¶ After this the name Nipigon was applied not only as a local designation (according to the suggestion of Hunt), but also by many as a more comprehensive term. In this more comprehensive sense it has not only been made to include all the post-Animikie rocks in the vicinity of Nipigon bay and lake, but has been used as a general designation for the copper-bearing rocks of lake Superior, thus being synonymous with Keweenawan. Bell himself uses Nipigon as referring only to the upper divis-

*Geol. Survey of Canada, Report of Progress for 1872-'73, pp. 87-111, 1873.

†Geology of Canada, pp. 67-86, 1863.

‡Geol. Survey of Canada, Report of Progress for 1872-'73, p. 106, 1873.

§Amer. Jour. Sci., 3d series, vol. 11, p. 210, March, 1876.

Second Geol. Survey of Pa., E, "Azoic Rocks, Pt. I," p. 241, 1878.

¶Trans. Amer. Inst. Min. Eng., vol. 1, p. 342.

ion of the Upper Copper-Bearing series of Logan,* and not as originally proposed to include both upper and lower divisions.

It thus appears that the term Nipigon, especially as compared with Keweenawan (or some form of this name), has little claim as a general age designation for the copper-bearing rocks of lake Superior. Moreover, it seems eminently fitting that a name derived from Keweenaw point, where the copper-bearing rocks occur in typical development and where they have been most carefully studied, should be perpetuated in the designation of this series of strata. But as to whether we call them Keweenian, Kewenian, Keweenawian or Keweenawan is not very important. However, the last form (Keweenawan) has been more generally used than any other, and is the one adopted in the reports of the Wisconsin and United States Geological Surveys, and is used by Prof. C. R. Van Hise in his correlation paper on the Archean and Algonkian.† It thus, on the whole, seems the most appropriate and its use will engender less confusion than that of any other. U. S. GRANT.

Minneapolis, Feb. 8th, 1895.

DRUMLIN ACCUMULATION. After hearing and seeing Prof. Chamberlin's exceedingly instructive presentation of his observations and photographic views taken in Greenland, as noted in the report, on following pages, of papers at the recent meeting of the Geological Society, I have thought that it may be useful to point out the several features of drumlins, and portions of my explanation of their mode of accumulation, which receive illustration in the glaciers of the Inglefield Gulf region.

1. The large amount of englacial drift in these glaciers is all that my theory of drumlin formation requires. Professor Chamberlin supposes this to be nearly all derived from rock knobs and hills, whence the onflowing ice sweeps away the drift into its closing currents on the lee side. While this must be true, if there are such hills, for part of the englacial drift, it seems fully proved by the Pinnacle hills at Rochester, N. Y., by Bird's hill near Winnipeg, etc.,‡ that the North American ice-sheet on some nearly level areas gathered much drift into its lower part by upwardly flowing currents; and such, too, I think to have been the mode of derivation of the greater part of the Greenland englacial drift.

2. The oval form, moulded (not sculptured) in the process of growth of the drumlins; their accretion of new drift simultaneously over all their surface; the lamination of their till, now apparently due to this gradual accretion rather than to the ice pressure; and the frequently observed downward and upward curving lamination in the drumlin till where it encloses boulders,—all these noteworthy features are well exhibited by the englacial drift and the little submarginal drumlins seen in process of formation from it beneath the terminal ice-cliffs of these glaciers near Bowdoin bay.

3. The place, with relation to the ice-sheet, of the formation of our

*Report of the Royal Commission on the Mineral Resources of Ontario, pp. 2, 30-39. Toronto, 1890.

†U. S. Geol. Survey, Bull. No. 86, 1892.

‡Bulletin, Geol. Society of America, vol. v, pp. 71-84, Jan., 1894.

Pleistocene drumlins, which, as I have shown, was under the *border* of the retreating ice, estimated to have reached in some instances no more than a mile in front of the drumlin while it was being amassed; their englacial source of drift supply; and the concentration of this drift into layers in the basal part of the continental glacier, so that it became rapidly heaped by converging currents in these lenticular hills,—again, all these characteristics are displayed in the Greenland photographs.

4. Seeing the englacial drift there so remarkably gathered into distinct layers, I now think it probable that drumlin accumulation was not usually, perhaps indeed was never, dependent on the process of the englacial drift becoming superglacial by ablation and afterward being enveloped by the ice of increased snowfall and onward glacial flow, which I have supposed requisite for the evidently rather rapid heaping together of so large amounts of the glacial drift. The statement of my theory given in the AMERICAN GEOLOGIST (vol. x, pp. 339 362, Dec., 1892), and in the Proceedings of the Boston Society of Natural History (vol. XXVI, pp. 2-17, for Nov., 1892, with ensuing discussion by Prof. W. M. Davis and Mr. George H. Barton), seems therefore to be now well sustained, excepting that the most cumbersome part of the supposed preparation for drumlin-making now appears superfluous, Nature's method being more simple and direct.

Other conditions of variability in the rate and manner of departure of the ice-sheet may account for the geographic distribution of the drumlins, as certain areas of their abundance, neighboring tracts where they are more scattered, and the rare occurrence of lone drumlins, yet of large size and typical form. With much englacial drift gathered in layers and patches in the lower part of the ice-sheet, the inequalities of ablation and superglacial drainage, when extended at certain times over a somewhat broad belt of the ice-border, may have produced convergent currents of the lower ice sufficient for amassing these hills in all their variety of grouping and occasional solitary occurrence.

Feb. 9th, 1895. WARREN UPHAM.

PERSONAL AND SCIENTIFIC NEWS.

DR. GEORGE M. DAWSON, C. M. G., F. R. S., was appointed Director of the Geological Survey of Canada on January 10th, succeeding Dr A. R. C. Selwyn, retired.

THE COUNCIL OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE held a special meeting on January 26th and decided to postpone the proposed meeting in San Francisco. An invitation from Springfield, Mass., to hold the meeting of 1895 in that city, was accepted. The date of the meeting was fixed as follows: Council meeting, Wednesday, August 28th, at noon; general sessions, Thursday, August 29th, at 10 a. m.

THE SIXTH INTERNATIONAL GEOGRAPHICAL CONGRESS will meet in London from July 26th to August 3d, 1895. The

headquarters of the Congress are at the house of the Royal Geographical Society, 1 Savile Row, Burlington Gardens, London, W. Information in regard to this meeting can be obtained from the secretaries, J. Scott Keltie and Hugh Robert Mill, at the above address.

THE LEGISLATURE OF THE STATE OF WASHINGTON is considering a bill for the establishment of a state geological survey, and a strong pressure is being brought to bear upon the Legislature to convert it into a topographical survey, under the direction of the United States Geological Survey.

A MOST IMPORTANT PUBLICATION of the Missouri Geological Survey has been issued in a few advanced copies, unbound and without the plates and maps. It is by Arthur Winslow and J. D. Robertson, on the lead and zinc deposits of Missouri. We postpone full review till the work is completed.

THE THIRD ANNUAL MEETING of the Lake Superior Mining Institute will be held in Minnesota on the 6th, 7th and 8th of March. The members in attendance will be taken over the Mesabi and Vermilion iron ranges, and evening meetings will be held at Virginia and Tower. Papers will be read by Dr. L. L. Hubbard, state geologist of Michigan; Dr. U. S. Grant, assistant state geologist of Minnesota; Mr. F. W. Denton, secretary of the institute; Mr. Wessinger, master mechanic of the Minnesota Iron Company, at Soudan, and others. Members will be present from all portions of the lake Superior region, and a successful meeting is assured. Some account of the papers read will appear in our April number.

THE DEPARTMENT OF GEOLOGY AND PALEONTOLOGY in Union College, Schenectady, New York, which is being organized by Prof. Charles S. Prosser, offers several courses in advanced geology. Particular attention is given to the stratigraphic geology and paleontology of New York state, and during the spring and fall terms much time is devoted to field work in the Mohawk valley and the Helderberg mountain region. As New York is the classic state in American geology such courses of instruction are well adapted to train students in the methods of geological investigation and for professional work.

PROF. O. C. MARSH, in the American Journal of Science for February, has given an account of the highly interesting memoir by Eug. Dubois on the remains of what is a veritable "missing link" between the higher apes and man. Of the new form (*Pithecanthropus erectus*), which is believed to represent a new genus and a new family intermediate between the *Simiidæ* and the *Hominidæ*, a skull, a molar tooth and a femur have been found in volcanic tufa of later Tertiary age in central Java. In size, brain power, and erect posture, this species is much nearer to man than any animal hitherto discovered, living or extinct.

PLEISTOCENE PAPERS AT THE BALTIMORE MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA.

Most prominent among the Glacial and Pleistocene papers presented before the Geological Society of America at its Baltimore meeting, Thursday to Saturday, December 27–29, 1894, was the Presidential Address by Prof. T. C. CHAMBERLIN, *Recent Glacial Studies in Greenland*, which was given on Friday evening. The address was followed by the exhibition of a large series of admirable photographic lantern views of the glaciers, their enclosed drift, and their marginal morainic deposits. The district most thoroughly examined borders the north side of Inglefield gulf, near latitude 78°, where Prof. Chamberlin and others of the Peary Relief Expedition spent about three weeks in last August at Lieut. Peary's winter station on Bowdoin bay, in the midst of many and diversely developed glaciers, flowing both from the inland ice-sheet and from local outlying fields of névé on the coastal mountains. Notes taken during this address supply the following summary or abstract:

The glaciers in the vicinity of Bowdoin bay, where terminating on the land, commonly have very steep, often nearly vertical and sometimes overhanging fronts to hights of 100 to 200 feet or more. This remarkable contrast with the glaciers of more southern latitudes is ascribed to peripheral melting by reflection of the oblique solar rays from the warm adjoining ground. It seems also to be secondarily dependent on the very slow rate of the glacial motion, which is found by Peary to be usually scarcely measurable, while the maximum daily rate observed in exceptionally fast-flowing glaciers in the midsummer is from 2¼ to 4 feet.

Englacial drift is plentifully seen in many of the frontal ice-cliffs to hights of 50 to 100 feet and occasionally 150 feet, or about half of their total hight. It is quite unequally distributed, being commonly gathered, especially at considerable hights, into layers of an inch to a foot or more, where the ice contains much rock detritus, interbedded with thicker layers of nearly pure ice. Again, masses of drift several feet in extent, analogous with till, are rarely enveloped in the ice, which, above and beneath these masses and the similarly enclosed boulders, has an upwardly and downwardly arching lamination.

Differential onward flow of the ice, its upper and middle portions outstripping those next beneath, has been the chief means of giving to the terminal ice-cliff sections a very distinctly and surprisingly laminated structure. Sometimes the differential movement has carried part of a previously plane zone forward so much faster than that which was before it as to bend the clearly laminated zone into sigmoid folds and even to produce sharply defined overthrust faults. In this way the englacial boulders and small rock fragments are frequently much worn and striated.

The inclusion of the englacial drift is attributed to abrasion from knobs and ridges standing up into the overriding ice, rather than to any upwardly flowing basal currents. It is observed, however, that the front of the ice sometimes rides upward over its own marginal accumulations of drift; indeed, wherever onward movement of the ice boundary is taking place, this seems more frequent than any glacial erosion or pushing forward of the moraine. Strong winds blow prevailingly down the slope of the inland ice, often drifting snow over the

frontal glacier cliffs, and even these snow drifts are sufficient in some places to cause the ice to flow upward or to be laterally deflected.

In some cases the morainic hillocks, seen in process of formation beneath the steep or vertical edge of the ice, have the outlines of miniature drumlins, with the laminated glacier curving upward quite conformably over them. No eskers or kames were observed. The drainage from the glacial melting is mostly by subaërial lateral streams, along the inner side of the adjoining moraines; rarely it is by central subglacial streams.

Only very scanty drift is spread over the country outside the ice-sheet and glaciers; and the largest glacio-fluvial delta fans are about a half mile in extent. Most of the glaciers have been long stationary: a few are retreating: others are advancing.

Near the east side of Bowdoin bay a driftless area, having a diameter of three or four miles, shows deep decomposition of its rock, which is hornblendic gneiss. Its altitude is less than that of neighboring glaciers, and it is accepted, with the jagged and unglaciated outlines of the upper part of many of the coastal mountains from capes Farewell and Desolation north to Inglefield gulf (a distance of 1,200 miles), as decisive evidence that there has never been a complete envelopment of the western border of Greenland by land ice.

Dalrymple island, close to the Greenland coast, near long. 70° and lat. 76° 30′, also consists of decomposing hornblendic gneiss, with no drift, and with mountain forms due solely to subaërial erosion. Fifty miles northwestward, however, the Carey islands, which are mountains rising from a large expanse of the surrounding northern part of Baffin bay, have been glaciated by an ice-sheet flowing over them from the north, that is, from Grinnell land and Smith sound. In the course of this ice-sheet, at a distance of fifty miles north of the Carey islands, the sea has a depth of 220 fathoms.

Inquiring for the physical causes and explanation of glacial motion, Prof. Chamberlin thinks the theory of Hugi, Grad, Forel, and others, which refers the movement, under the influences of the solar heat and gravity, to the enlargement and long persistence of the granules originating in the névé, to be more supported by his observations and studies than the now commonly accepted theory of J. D. Forbes, which regards the ice as a viscously flowing, though brittle, solid. (These Greenland glacial studies, upon a wider range than could be noted in this address, are being presented very fully by Prof. Chamberlin in a series of articles in the Journal of Geology, from the number for Oct.-Nov., 1894, onward.)

Nine other papers related to the Ice age and Pleistocene history, of which abstracts, with notes of their discussion, follow:

Observations on the Glacial phenomena of Newfoundland, Labrador, and southern Greenland. By G. FREDERICK WRIGHT. From glacial drift deposits and striæ it seems conclusive that the ice-sheet of Labrador extended out upon the submerged plateau surrounding Newfoundland so as completely to envelop the island; but probably the whole region was then elevated above its present level about 2,000 feet, in which case the ice-sheet also may have likewise enveloped the very large area of the now submerged Grand Bank, yet without then reaching to the sea level. The evidences for these conclusions are (1) that glacial scratches are found on the summits of all the headlands of Newfoundland up to 550 feet, pointing out to the open sea; (2) that the basins of some of the inland lakes of the island descend nearly 1,000 feet below the level of the sea: and (3) that the submerged plateau of the Fishing Banks is intersected by a deep channel extending across the Gulf of St. Lawrence to the edge of the abyssal water of the Atlantic. Furthermore,

the coast of Labrador is characterized by the graceful flowing contour which is produced by the horizontal erosion of ice rather than of subaërial agencies. This is in striking contrast to the border of western Greenland, which was seen by Prof. Wright last summer, in the Cook Arctic Expedition, for a distance of 300 miles. In both cases the rocks are Laurentian gneiss, which would weather into the same shapes if subjected to the same conditions. The mountainous border of western Greenland has never been entirely covered by glacial ice, but has been subjected for an indefinite time to subaërial erosion, producing the innumerable sharp needle-like peaks. The evidences, however, of a former great extension of the inland ice-sheet of Greenland are everywhere visible; but these peaks (from 2,000 to 4,000 feet in hight) were always nunataks, and the ice probably never reached as far out into Davis strait as it did from Labrador toward the southeast.

A striking fact, noted in both southern Greenland and Labrador, is the small amount of glacial drift still remaining on the land now free from ice. There is scarcely any till in either region, and even boulders are few as compared with tracts near the border of the glacial drift in the central parts of the United States. The explanation is, doubtless, that the present Greenland and Labrador coasts were so far within the areas of Pleistocene glaciation that the loose material was nearly all removed and deposited in the sea.

Professor Wright spent some time on a projection of the inland ice, three miles wide, which comes down into Ikamiut fjord about fifteen miles from the open sea, near Sukkertoppen, in latitude 65° 50′. The ice there scarcely differs from that of the Muir glacier in Alaska. It has vast moraines on its surface, but little or no englacial material. The scratches on the margins of this fjord present instructive complications. When the ice filled the fjord to the hight of about 2,000 feet, the scratches were in the direction of its axis; but, now that it has retreated, local glaciers are producing striæ at right angles to these, and in some cases even in an opposite direction. (This paper is published in the American Journal of Science for February, 1895.)

Highland Level Gravels in northern New England. By C. H. HITCHCOCK. At the south end of lake Memphremagog terraces of sand and gravel, regarded as deltas of a glacial lake held by the barrier of the departing ice-sheet, occur at hights of 575 feet and especially at 250 to 275 feet above the lake, which is 695 feet above the sea. These terraces are best developed near the mouths of Barton and Black rivers, and they extend nearly horizontal up the valleys of these streams, which flow into the lake from the south. Other terraces, having hights of 1,100 feet or more above the sea, are known north of lake Memphremagog; and they occur at similar altitudes in northern Maine. Their greatest hight is in the White mountains of New Hampshire, where, near the Twin Mountain House, a very remarkable delta-like deposit of sand and gravel is found 1,500 feet above the sea level.

Referring to the opinion of Chalmers and others of the Canadian Geological Survey, that the glaciation of New England and New Brunswick may have radiated outward in all directions from their mountainous central region, Prof. Hitchcock thought this view disproved by the transportation of boulders from the north side of the St. Lawrence to its southern watershed in Maine, and by the southeastward glacial striæ and drift transportation on Mt. Katahdin and Mt. Washington. During the closing stage of the Glacial period, however, local glaciers or remnants of the continental ice-sheet flowed outward perhaps from all sides of the mountain region, and some of the valley moraines have been observed by Agassiz, Stone, and the author. This Late Glacial stage probably comprised the northward movement of boulders noted in some parts of northern New England and the eastern provinces of Canada.

Prof. J. W. SPENCER, discussing this paper, attributed the high terraces to deposition at the sea level, when New England was depressed 1,000 to 1,500 feet: and he thought the maximum subsidence indicated in the White mountains to be about 2,000 feet.

Variations of Glaciers. By HARRY FIELDING REID. Great interest has been aroused lately in the study of the variations of glaciers. Observations on the glaciers of the Alps have shown that their dimensions undergo a periodic change: that they increase, attain a maximum, decrease, reach a minimum, and begin to increase again, going through such a cycle two or three times in a century. Records of more or less exactness extend back two or three hundred years. Glaciers, however, are not all in the same phase at the same time: indeed, some begin to advance when others have almost reached their maximum. Glaciers side by side are sometimes found in opposite phases. This makes it difficult to determine the relation between variations of climate and of glaciers, but some progress has been made. The theories of Richter and of Forel, advanced to explain this peculiar behavior of glaciers, were presented. Accurate and extended information is wanted concerning the changes that glaciers undergo. At the International Congress of Geologists in Zurich last summer, a committee was appointed to collect information on this subject all over the world: and the author, who is one of this committee, desires notes from all American observers (address: Johns Hopkins University, Baltimore, Md.). The remainder of the paper gives methods, from the simplest to the more difficult, of observing and recording the extent of glaciers. (This paper is to be published in the Journal of Geology.)

Discrimination of Glacial Accumulation and Invasion. By WARREN UPHAM. The accumulation of ice-sheets by snowfall on their entire area is discriminated from an advance or invasion by the front of the ice, extending it thus over new territory. The former condition is shown to have been generally prevalent, on the glaciated portions of both North America and Europe, by the occurrence of comparatively small areas of ice accumulation beyond the extreme boundaries of the principal ice-sheets. The latter condition, or ice invasion, is indicated on the outer part of the drift-bearing area eastward from Salamanca, N. Y., through Staten and Long Islands, Martha's Vineyard, and Nantucket, where the soft strata beneath the ice were dislocated and folded.

Near the margin of drift-bearing areas, glaciation chiefly due to snow and ice accumulation, with less supply by inflow from central and thicker tracts of the ice-sheet, is indicated, as the author thinks, by a gradual attenuation of the drift, absence of morainic knolls and hills, and scanty glacial erosion of the bed-rocks.

Conversely, the evidences of an invasion of the ice-sheet upon its marginal tracts consist in thick drift deposits, hilly moraine belts, and much planing and striation of the rock surface. Displacement and folding of soft strata beneath morainic deposits seem to be especially conclusive proof of vigorous incursion by a steep ice-front.

Reädvances of the ice within its drift area may be recognized by very clearly defined belts of morainic hills, pushed out upon smooth tracts of till, or by the very rare occurrence of disrupted or deeply crumpled underlying beds. In most cases where moraines belonging to the time of general glacial recession are conspicuously hilly on their outer side, they record some glacial reädvance, rather than a mere halt or a slackening in the rate of retreat.

Climatic Conditions shown by North American interglacial deposits. By WARREN UPHAM. During the times both of general accumulation and growth of the ice-sheets and of their final recession, fluctuations of their borders were recorded in various districts by forest trees, peat, and

molluscan shells, enclosed in beds underlain and overlain by till. Such fluctuations, while the ice accumulation was in progress, enclose chiefly arctic or boreal species: but when the ice was being melted away, in the Champlain epoch, the remains of the flora and fauna thus occurring in interglacial beds, as at Toronto and Scarboro', Ont., may belong wholly to temperate species, such as now exist in the same district. The cold climate of the Ice age appears thus to have been followed by a temperate Champlain climate close upon the waning ice-border.

From this review of the drift deposits and of the climatic and glacial oscillations, the minor time divisions of the Ice age are tabulated provisionally as follows, in accordance with the nomenclature for the glacial stages which is proposed by Chamberlin in the new edition of Geikie's "Great Ice Age." The two stages of growth of the ice-sheet may have been due, aside from their principal dependence on the high elevation of the land, to the climatic effects of the last two passages in the precession of the equinoxes, with accompanying nutation, bringing the winters of the northern hemisphere in aphelion about 30,000 years ago, and again about 10,000 years ago. This explanation, which may be good ground for a compromise between the lately opposing views of unity and of duality or greater complexity of the Glacial period, agrees with Prof. N. H. Winchell's well known computations from the rate of recession of the falls of St. Anthony for the Postglacial or Recent period, and with his estimate of the duration of the Interglacial stage. (AM. GEOLOGIST, vol. x, pp. 69-80, with sections and map, Aug. 1892) from the now buried channel which appears to have been then eroded by the Mississippi river a few miles west of the present gorge below these falls. The order of the table is stratigraphic, so that for the sequence in time it should be read upward.

EPOCHS AND STAGES OF THE GLACIAL PERIOD.

CHAMPLAIN EPOCH (Land depression; disappearance of the ice-sheet; partial re-elevation of the land.)	WISCONSIN STAGE (Progressing re-elevation.)	Moderate re-elevation of the land, advancing as a permanent wave from south to north and northeast; continued retreat of the ice along most of its extent, but its maximum advance in southern New England, with fluctuations and the formation of prominent marginal moraines; great glacial lakes on the northern border of the United States; slight glacial oscillations, with temperate climate nearly as now, at Toronto and Scarboro'; the sea finally admitted to the St. Lawrence, Champlain, and Ottawa valleys; uplift to the present hight completed soon after the departure of the ice.
	CHAMPLAIN SUBSIDENCE.......	Depression of the ice-covered area from its high Glacial elevation; retreat of the ice from its former Iowan limits; abundant deposition of loess.
GLACIAL EPOCH (Ice accumulation, due to the culmination of the Lafayette epeirogenic uplift.)	IOWAN STAGE.....	Renewed ice accumulation, covering the forest beds and extending south nearly to its early boundary.
	INTERGLACIAL STAGE	Extensive glacial recession in the upper part of the Mississippi basin; cool temperate climate and coniferous forests up to the waning ice border; much erosion of the early drift.
	KANSAN STAGE....	Maximum extent of the ice-sheet in the interior of North America, and also eastward in northern New Jersey.
	UNDETERMINED STAGES of fluctuation in the general growth of the ice-sheet.	Including an early glacial recession and reädvance, as shown by interglacial beds of lignite, in the region of the Moose and Albany rivers, tributary to James bay.

Prof. R. D. SALISBURY, in discussion of the two preceding papers, preferred the term "ice invasion," even for the glacial stages marked

by attenuated drift borders; and he doubted that high elevation of the land was coincident with the growth of the ice-sheet.

Prof. CHAMBERLIN spoke of the two thick deposits of till interbedded with fossiliferous stratified clay and sand at Scarboro', as indicative of great climatic changes and long stages of glacial reädvance.

Glacial Lakes in western New York. By H. L. FAIRCHILD. The course of marginal moraines extending from west to east across the region of the Finger lakes in central New York shows that the glacial recession there was in general from south to north. This is a region of strongly marked and peculiar topographic features, consisting of long south to north valleys, often deeply eroded continuously across the watershed which divides the sources of the Alleghany and Susquehanna rivers from the lake Ontario basin, with plateaus several hundred feet above the meridional valleys. During the retreat of the ice-front, therefore, it was a barrier holding long glacial lakes in the valleys, with channels of outflow over the present watershed. Within the past autumn, field exploration of the Finger lakes region has resulted in recognition of eighteen such ice-dammed lakes, which are named in this paper, with few exceptions, from the principal towns in the formerly lacustrine valley or on its outlet. In their order from west to east these Pleistocene lakes are thus named the Attica, Warsaw, Upper Genesee, Dansville, Scottsburg, Springwater, Glacial Canadice, Glacial Honeoye, Bristol, Naples, Flint, Hammondsport, Watkins, Ithaca, Groton, Glen Haven, Glacial Otisco and Tully Valley lakes. Descriptions of several of them are given in the following notes.

The Dansville glacial lake, in the valley basin of the present Canaseraga creek, had a length of about 24 miles, a width of two miles, and a depth exceeding 500 feet. Its outlet is at a hight of about 1,200 feet above the present sea level, and the old lake shore terraces and deltas are at 1,230 feet.

Coming forward to the Naples glacial lake, the tenth of the series, in the valley of Canandaigua lake, its length is shown to have reached about 13 miles, with a width of two miles and depth of quite 700 feet over the present lake, before the continued glacial recession permitted it to be merged with the vastly larger glacial lake of the whole Ontario basin. Its channel of overflow southward is now 1,340 feet above the sea.

The ancient Hammondsport lake, now represented by lake Keuka, became about 24 miles long, two miles wide, and more than 500 feet deep. Its mouth is 1,125 feet above the sea, or somewhat more than 400 feet above the present lake Keuka. The old deltas and other traces of the highest shore line are approximately at 1,150 feet.

Watkins lake, as the glacial representative of Seneca lake is called, grew to be 30 miles long, four miles wide, and 1,000 feet deep. Its southward outflow, the lowest of all the series, is 900 feet above the sea (or 460 feet above the modern lake), and its highest deltas are at 960 feet.

The glacial Ithaca lake, now Cayuga, attained a south to north extent of perhaps 35 miles, with a width of 5 to 10 miles, and depth of 1,100 feet. At its beginning one outlet, in the continuation of the Cayuga valley, was 1,024 feet above the present sea level; but a lower pass in the southeast valley was uncovered by the glacial recession, causing the western branch to fall suddenly about 40 feet. The lower or principal outlet, at 967 feet, is 589 feet above Cayuga lake.

Lake Newberry, the successor of Lake Warren. By H. L. FAIRCHILD. It has long been known that when the ice-sheet covered western New York the great Laurentian lakes discharged at Chicago to the Mississippi; and the far expanded glacial lake thus held by the ice barrier and cov-

ering the present areas of lakes Superior, Michigan, Huron, and Erie, with definite beaches from a few feet to hundreds of feet above these lakes, is called lake Warren. At a much later stage, when the Mohawk was uncovered, the waters ran to the Hudson, and the great lake on the site of Ontario has been called lake Iroquois. During an intermediate stage between these two, it is suggested that the discharge of the water covering western New York and the present Laurentian lakes farther west was through the low pass south of Seneca lake, which has its water divide, 900 feet above the sea, at the town of Horseheads, near Elmira. The former existence of this large glacial lake, which is here named in honor of the late Prof. J. S. Newberry, is believed to be possible when allowance is made for the depressed condition of the area at that time.

In the ensuing discussion, Mr. G. K. GILBERT thought no other name could be more fittingly chosen, but doubted that the Seneca lake pass ever carried the outflow of so extensive a glacial lake as this had been described.

Prof. SPENCER and Mr. UPHAM also spoke in high approval of the proposed name, but thought that, if the large lake ascribed to the Seneca pass existed, it would be found to be the same which these authors have described within the past year under the name Lake Lundy, given by Spencer from the Lundy lane, of historic renown, a "ridge road" on its principal beach west of the Niagara river.

Notes on the Glaciation of Newfoundland. By T. C. CHAMBERLIN. The southeastern or Avalon peninsula of Newfoundland was glaciated from its center outward in all directions, excepting that on the northern part of the isthmus or neck uniting it with the main island the glaciation was southeast toward the peninsula. Local derivation of the drift is very remarkable. The Avalon nucleus consists of granite and schists, but its coastal belt is largely Cambrian red sandstone. On the east coast, in the vicinity of St. Johns, nearly all the glacial drift is from the underlying and contiguous sandstone; but in going a few miles back to the Huronian area, the drift there is found to consist chiefly or wholly of the crystalline rocks, with no sandstone. Much kame gravel was noted on the isthmus. The author agrees with Murray and Howley in regarding the glaciation as continuous with that of Labrador; but, in view of the northward as well as eastward and southward radiation of drift action ascertained by the thorough explorations of Chalmers in New Brunswick and of others in the Gaspé peninsula, with Richardson's description of the Magdalen islands (Geol. of Canada, Report of Progress for 1879-80, Part G), showing that those islands near the center of the Gulf of St. Lawrence are driftless and have not been ice-covered, Prof. Chamberlin thinks that the Newfoundland ice reached not far beyond the present shores of the island on the southwest, south, and east.

Prof. HITCHCOCK, in comment on the radiating courses of glaciation in Newfoundland and New Brunswick, directed attention to the resemblance of these areas to the great lobes of the ice-sheet in the region of the Laurentian lakes and the upper Mississippi. He concludes that the glacial currents over New England came from the highlands north of the St. Lawrence, for the courses of glacial striation on the summits of the White mountains and of the Green mountains are from northwest to southeast. The highest mountains of Newfoundland will probably be found similarly striated.

The Surface Formations of southern New Jersey. By ROLLIN D. SALISBURY. The Yellow Gravel series, which until recently has seemed very perplexing for explanation of its origin and history, is found to comprise four distinct formations, with a wide range in age. The earliest is named

the Beacon Hill formation, from its capping a hill of this name three miles south of Matawan. There and eastward on the Navesink Highlands the altitude of its surface is about 400 to 300 feet above the sea, declining toward the east and south, and it has a maximum thickness of about 100 feet. It consists of sand and gravel, often containing pebbles up to three inches in diameter, and occasionally having larger cobbles and even slab-like masses of sandstone up to two feet. The Beacon Hill formation lies on Cretaceous beds which had a nearly plane surface at the time of its deposition; but the Cretaceous series made little or no contribution to it. Neither has it any pebbles of granite, gneiss, trap, gabbro, limestone, or Triassic sandstone or shales. Instead, its gravel is the longer enduring quartz, chert, and Hudson River sandstone. In Monmouth county the greater part of the Beacon Hill gravel and much of the underlying Cretaceous strata have been eroded, the general denudation being 150 to 250 feet and the deepest valleys about 100 feet lower.

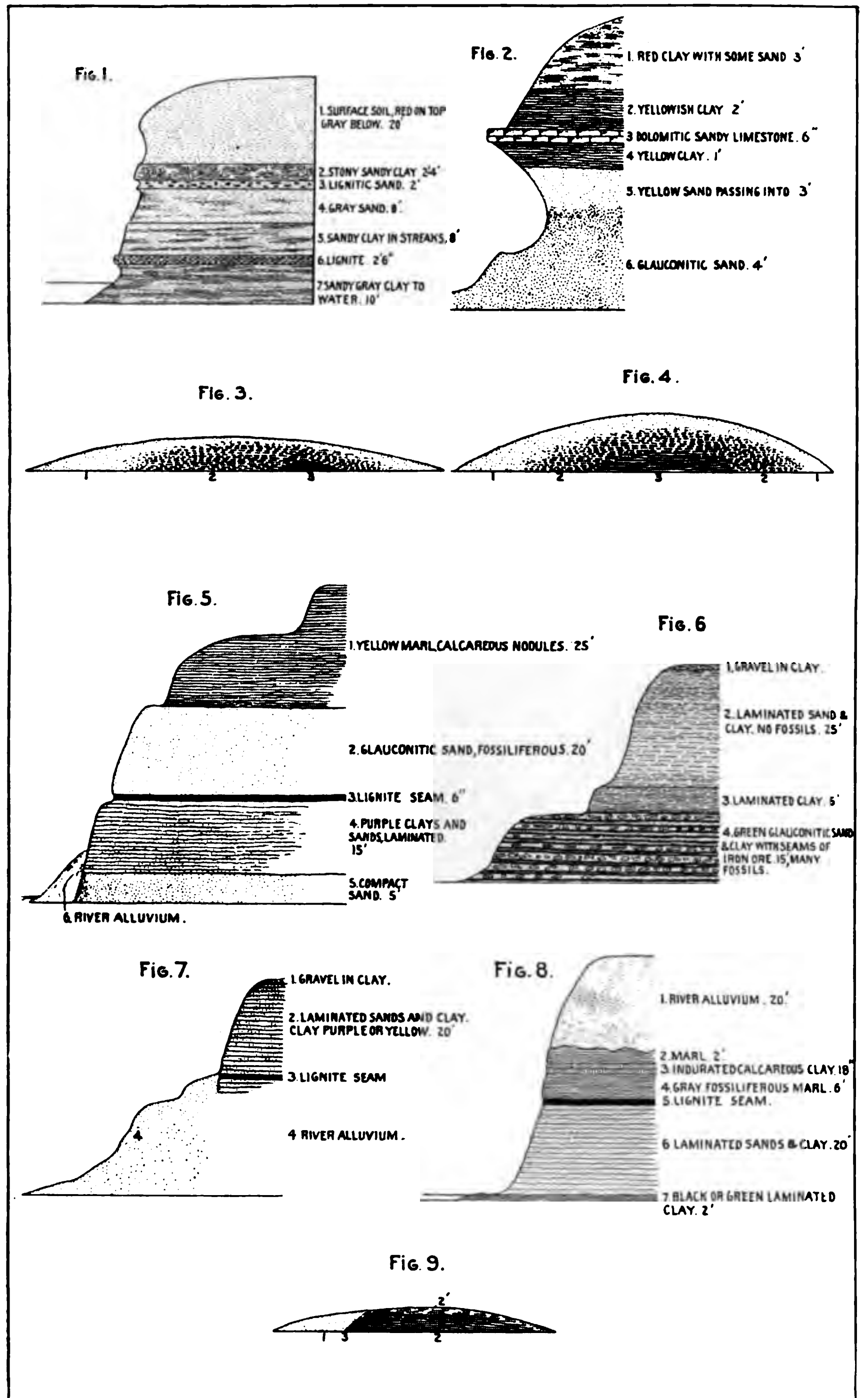
Following this great denudation, the second or Pensauken formation, ranging up to 50 or 60 feet in thickness, was spread over the lowlands and valleys to the hight of 150 to 200 feet above the sea. Its pebbles and cobbles range in size up to one foot or sometimes two feet in diameter; and it contains boulders, especially northeastward near the glacial drift boundary, which were doubtless borne by floating ice, up to two, three, or even four feet. The gravel and boulders comprise granite, gneiss, Triassic shale and sandstone, gabbro and trap, besides much quartz, chert, etc.; but a very characteristic feature is the prevailingly decayed condition of the granitic and gneissic material, which underwent this change after deposition.

Much erosion of the Pensauken deposits had again brought the drainage system to a mature stage of development, when the third or Jamesburg formation was laid down in the valleys under 130 or 150 feet above the sea. This is a thin mantle of commingled gravel, sand, and loam, averaging no more than ten feet thick, frequently inclosing boulders, some of which are glacially striated. Subsequent stream erosion has been slight.

The fourth or Trenton gravel formation, lying in the river valleys below the comparatively high limit of the Jamesburg loam and sand, is too well known to need particular description. It belongs to the late moraine-forming stage of the Glacial period.

The Beacon Hill, Pensauken and Jamesburg formations are attributed to marine and estuarine deposition, with intervening epeirogenic uplifts of the land. It is held by the author as still questionable, whether the first is of Miocene or of Lafayette age; whether the second represents the Lafayette or the Columbia of the Atlantic coastal plain farther south; and whether the third belongs to the earliest or to some later stage of the general northern glaciation.

Mr. UPHAM, in discussion, called attention to the total lack of marine fossils in all these formations, and to the absence of shore lines marked by wave erosion and beach ridges; hence he would refer all the Yellow Gravel series to fluvial deposition while the land had a greater altitude than now. [From advance sheets of the Annual Report of the New Jersey geological survey for 1893, received, since the Baltimore meeting, from Prof. John C. Smock, the state geologist, and from Prof. Salisbury, whose more full descriptions of these formations are there presented, it seems well demonstrable that the great denudation between the Beacon Hill and Pensauken formations should be considered as the same with that intervening farther south between the Lafayette and Columbia formations, to be accounted for by the great preglacial altitude to which the land was raised subsequent to the epoch of deposition of the Lafayette beds, finally culminating with a high plateau climate and ice accumulation upon the northern half of the continent.—W. U.]



STRATIGRA' NORTHWESTERN LOUISIANA.

THE

AMERICAN GEOLOGIST.

VOL. XV. APRIL, 1895. No. 4.

THE STRATIGRAPHY OF NORTHWESTERN LOUISIANA.*

By T. WAYLAND VAUGHAN, Washington, D. C.

(Plate IX.)

CONTENTS.

INTRODUCTION: AREA DEFINED.

The following paper contains a résumé of the results of a somewhat protracted study by the author of that portion of

*Published by permission of the Director of the U. S. Geological Survey.

In this work I have received courtesies and assistance from several gentlemen to whom I desire to express my obligations. To Dr. Otto Lerch I am indebted for many suggestions while in the field with him. He also submitted to me for study the collection of the Louisiana Geol. Survey. To Dr. Wm. H. Dall, Prof. Angelo Heilprin, Mr. H. A. Pilsbry, Dr. C. E. Beecher, and Prof. R. P. Whitfield, I owe my thanks for access to the collections under their charge. To Dr. Dall and Mr. R. T. Hill I am indebted for advice. Mr. G. D. Harris has rendered me great assistance in helping me determine some of the fossils, especially those which he has named, the descriptions of which have not yet appeared in print. To Dr. Robt. T. Jackson, Prof. N. S. Shaler and Mr. L. S. Griswold of Harvard University I am thankful for advice.

Louisiana bounded in a general way by the Arkansas and Texas lines, by the Ouachita river as far south as Harrisonburg, by a line running thence to Alexandria on the Red river, and thence northeast to a point west of Mansfield on the Sabine river. This study was begun in the fall of 1889; in 1892 it was the good fortune of the author to be assistant to Dr. Otto Lerch in his survey of the hills of northern Louisiana. From the fall of 1892 to the spring of 1894, while a student at Harvard University, I devoted a large portion of my time to preparing a report on the Eocene fossils of Louisiana. During the autumn of 1894, acting under instructions from the Director of the United States Geological Survey, the author returned to Louisiana to collect more fossils and to study further the general geology of the region. In the report for this Survey much more detail will be given than is here presented, and lists of the fossils with descriptions and figures of the new species will be included.

This area has been the subject of study by several able geologists. Conrad as early as 1834* announced the existence of Eocene in Louisiana from fossils sent him. Later Hilgard, Hopkins, Johnson, Lerch, Harris, and McGee, have done field work in that state. The publications of these geologists will be alluded to as reference to their work becomes necessary.

THE CRETACEOUS.

The existence of Cretaceous strata in Louisiana was first indisputably established by Hilgard in 1869.† Subsequently Hopkins, Johnson, and Lerch, have noted the occurrence of Cretaceous in that state. Dr. Lerch gives a list of the localities of these rocks on page 72, part 2, of his "Preliminary Report upon the Geology of the Hills of Louisiana." Cretaceous outcrops have been found in the following parishes in northern Louisiana: Webster, Bienville, Natchitoches, Winn and Rapides.

Hilgard observed that these outcrops when mapped form a line trending from northwest to southeast.‡ Associated with the outcrops of the Cretaceous are salt deposits; hard lime-

---

*Journal Acad. Nat. Sci., Phila., vol. VII, p. 120, 1834.

†Page 11. Preliminary report of a Geological Reconnoissance of Louisiana, in DeBow's New Orleans Review, Sept. 1869.

‡Op. cit., page 11.

stone, sulphur, and gypsum, are not infrequent. On Secs. 31 and 32, Twp. 10 N., R. 4 W., near Atlanta, in Winn parish, there outcrops a hard blue limestone which is traversed by minute fissures. In these fissures a small amount of gold has been found.

In the Cretaceous of Louisiana *Exogyra costata* has been found; as this fossil is characteristic of the Glauconitic division of the Upper Cretaceous, the strata in Louisiana bearing this fossil should be considered of Glauconitic age. Hilgard* mentions *Gryphæa pitcheri* also; but he is without doubt mistaken in his identification, as *G. pitcheri* is a Comanche series fossil and does not occur in the Upper Cretaceous.

The relations of the Eocene to the Cretaceous, as conceived by Hopkins,† is shown in a section across the state, published in his first report. He indicates that there are knobs of Cretaceous, around which the Eocene was deposited, but does not state explicitly the relation existing between the two series.

Dr. Lerch on page 72 of his Second Report gives the following explanation:

If we connect the above localities we obtain an irregular line with a northwesterly trend, revealing the distribution of the cretaceous deposits in north Louisiana as far as explored, over 1,000 feet in thickness. Nowhere outside of the outcrops bores have reached the cretaceous, not even in the nearest vicinity, wells of considerable depth have penetrated the shales of the lower lignitic and marine Claiborne which surround these islands. It is most probable, however, that at Shreveport the artesian bore, 1,100 feet in depth, has penetrated the tertiary strata and that the water flows from the upper cretaceous sands. Judging from the bores and exposures of this substructure of Louisiana and excluding the overlying later deposits, it represents a ridge with steep hillsides and occasional high peaks with almost perpendicular declivities. The exogyra costata and the gryphæa pitcheri found in close proximity in these outcrops, as well as the Eocene directly overlaying and resting against the cretaceous, seem to prove that at the close of mesozoic time enormous plutonic forces convulsed, fractured, faulted and folded the cretaceous strata, throwing up mountain chains of vast extent and raising them far above the waters of the gulf. It seems to us more than possible that these grand disturbances involve the whole of the southern cretaceous, and that the enormous downthrow along the balcones and the basaltic outbreaks along that fault are contemporaneous with the

*Prel. Rep. of a Geol. Reconn. of La., p. 11.

†First Ann. Rep. of the Geol. Sur. of La., p. 78, in the La. State Univ. Rep. for 1869, published 1870.

origin of the mountain chain in the tertiary of that state and of Louisiana. In the basins and embayments formed the Eocene strata were deposited, the very existence of which proves that there was no interva of a land period between the cretaceous and tertiary in this state, and if we could remove the covering mantle we would see the chains and peaks of limestone ranges formed at the close of the middle ages of our planet, altered somewhat by later erosion and denudation.

We are not prepared to agree with Dr. Lerch as to the correlation of the disturbance in Louisiana succeeding the close of the Cretaceous deposition, with the time of the Balcones faulting and the Pilot Knob volcanic activity. To discuss this subject fully here would require too much space.

We will emphasize the following facts, however. The Cretaceous outcrops in the area under discussion have a general southeast and northwest trend with knobs or peaks projecting along the line, and around these knobs the Eocene has been deposited. The occurrence of many of these projecting peaks would indicate a period of erosion intervening between the close of the Cretaceous and the beginning of the Eocene. Furthermore, the Cretaceous at the Winn parish marble quarry is almost horizontal, the limestone rising as a butte-like mass into the Eocene. If there had been a mountain chain, as Dr. Lerch maintains, with the Eocene deposited immediately thereafter, before erosion had degraded the limestone, the Cretaceous rock at the place under discussion should represent either a dome or an anticline, but such is not the case. In the mind of the author the most logical explanation of the relation of the Cretaceous to the Eocene is that a land period followed the close of the deposition of the rocks belonging to the former series.

The Tertiary.

THE EOCENE, ITS CHARACTERS AND DISTRIBUTION.

The Eocene of Louisiana has been the subject of more or less study ever since Conrad in 1834 announced the existence of strata of that age in the state. A good résumé of the early work done on the Eocene of this state has been given by Mr. G. D. Harris in his report, "The Tertiary Geology of Southern Arkansas," pp. 177-178.

The Eocene of this state is composed of lignitic clays and sands, the sands often cross-bedded, with the interstratification of beds bearing a littoral fauna; the fossiliferous beds

are occasionally impure limestone. Apparently, beds in one place bearing marine fossils, may in other places be represented by beds of the same age devoid of animal remains. Therefore, it is not at present possible to subdivide and correlate with accuracy all of the strata belonging to the Eocene period found in Louisiana.

The following are approximately the limits of the area occupied by the strata belonging to this period in Louisiana: On the north and west the Eocene of this state is continuous with that of Arkansas and Texas, on the south the boundary is formed by the Grand Gulf Miocene. This Miocene parting runs from a few miles south of Rosefield in Catahoula parish, by Centreville in the same parish, crossing Little river five or six miles below Georgetown, reaching the Red river five miles north of Colfax in Grant parish, and the Sabine river near the mouth of Bayou Negrut.*

Dr. Lerch has divided the Eocene as follows:

Vicksburg,
Jackson,
Arcadia clays, ⎫
Upper Lignitic. ⎪
Marine Claiborne, ⎬ Provisional names.
Lower Lignitic. ⎭

I shall propose the following scheme:

Vicksburg.
(Intervening lignitic clays.)
Jackson.
Cocksfield Ferry beds (equivalent, in a general way, to the Claiborne sands of Alabama).
Lower Claiborne, including *Ostrea sellæformis* beds, Lisbon beds, and Buhrstone.
Lignitic.

Lignitic Stage.

If this formation occurs in Louisiana it is only in the northwestern corner of Caddo parish and probably at Shreveport. I have seen at Port Caddo Landing in Harrison county, Texas, which adjoins Caddo parish, strata that I consider lignitic. If this point is connected with the point where Mr. Harris' Lignitic-Claiborne parting, as shown on his map of southern Arkansas, reaches the Arkansas-Louisiana state line,

*Some of the above data are taken from Hopkins: 1st. Ann. Rep. of La. State Geol. Surv., p. 99, for 1869, pub. 1870.

it will be seen that the northwestern corner of Caddo parish most probably is Lignitic. I have not been able to examine that area.

Lower Claiborne Stage.

This stage covers by far the largest area of any of the subdivisions of the Eocene in Louisiana, extending south from the Arkansas line to Georgetown, on Little river, to St. Maurice at the mouth of Saline bayou on the Red river, and to Provencal on the T. & P. railway. Lower Claiborne fossils have been found in Bossier, Webster, Claiborne, Bienville, Jackson, Winn, Natchitoches and Grant parishes.

In Alabama* the Lower Claiborne is divided into:

Ostrea sellæformis beds,
Lisbon beds, and
Buhrstone.

In Mississippi Dr. Hilgard† divides the Claiborne, below the Lignitic bed separating the Claiborne of that state from the Jackson, into

Calcareous, and
Silicious Claiborne.

Smith‡ writes: "From the section given in Hilgard's report, it seems that the middle part of what we have called the Claiborne series, containing the great number of *Ostrea sellæformis*, are the beds of the Calcareous division, best developed in that state."§

The Silicious Claiborne represents in large part the Buhrstone of Alabama. This formation in Alabama and Mississippi receives its name from the peculiar lithologic characters of its constituent rocks, which find no counterpart in Louisiana. As the Buhrstone in these two states is not characterized by well preserved fossil organisms, it is not possible to make any precise correlation in the Louisiana section.

The localities in which Lower Claiborne fossils have been found have already been indicated. The following are the general lithologic characters presented by that stage in Louisiana. In Caddo and De Soto parishes and in Natchitoches

*G. D. Harris: Am. Journ. Sci., April, 1894. Also see Smith and Johnson, Bull. 43, U. S. Geol. Sur., 1887.

†Agriculture and Geol. of Miss., p. 108, 1860.

‡Bull. 43, U. S. Geol. Sur., p. 25, 1887.

§The author is not altogether certain about Smith's correlation.

parish* as far south as Victoria, this formation is represented by lignitic sands and clays devoid of marine fossils, but lignitiferous strata occur throughout the whole area of the Lower Claiborne. In Bossier, Claiborne and Bienville parishes fossils are found as casts in sandstone, and as ferruginous replacements. In Webster, Bienville and Jackson parishes the fossils are usually obtained in glauconitic sands, although occasionally present in yellowish clay. Further south in the extreme southern portion of Bienville parish and in Natchitoches and Winn parishes, the fossiliferous beds are very calcareous and are rich in fossils, which are usually poorly preserved. *Ostrea sellæformis* is often extremely abundant. There are slight paleontologic differences to be found in the fauna contained in the calcareous clays or clayey limestones of northwestern Winn parish and of Natchitoches parish, as compared with the fauna found in the glauconitic sands to the northwest: but both faunæ are beyond doubt Lower Claiborne, and they are very closely related. From the southeast dip of the Eocene of Louisiana, it appears very probable that the calcareous beds above alluded to represent a horizon a little higher than the glauconitic beds to the north. Within the calcareous area at St. Maurice, Robertsville and Georgetown, Lower Claiborne fossils were obtained from glauconitic sands or greenish clays. These beds, from the close resemblance of their fossils to those found in the calcareous beds, in all probability represent local lithologic differences in the horizon to which the calcareous beds belong.

The Lower Claiborne formation rests conformably upon the lignitic, and passes conformably into the Cocksfield Ferry beds above.

Of Dr. Lerch's division the following belong to the Lower Claiborne:

Jackson (in part).
Arcadia Clays,
Upper Lignitic (in part),
Marine Claiborne,
Lower Lignitic (at least in part).

The sections shown in figs. 1,† 2, 3, 4, 5, and 6, plate IX, indicate the general characters of the stage.

*This part of the Lower Claiborne is Hilgard's Mansfield group.

†Fig. 1 is probably Lignitic.

At Shreveport it is difficult to decide whether the strata exposed should be considered Lignitic or Lower Claiborne, although they probably are Lignitic.

The Mansfield group of Hilgard should in all probability be referred to the Lower Claiborne. There is in the Mansfield group, so far as we know, a complete absence of animal remains, the formation being composed of lignitiferous sands and clays. The characters of the strata, however, are lithologically the same as those of the lignitiferous beds that occur within the northern part of the Lower Claiborne area between the Ouachita and Red rivers. The marine fossils found between these two rivers are always both overlaid and underlaid by lignitic strata. The Mansfield area lies south, southwest, and west of a part of the Lower Claiborne area in which marine fossils have been found. Making an approximate determination of the strike of the former beds, which is either north or northeast, the fossiliferous Lower Claiborne of Bossier, Webster, Claiborne and Bienville parishes, would be along the strike-line of the Mansfield. The inclination of these beds is so slight that only by accurate instrumental work can their dip and strike be determined with exactness. Lower Claiborne fossils have been found in Harrison county, Texas,* northwest of the outcrops of the Mansfield; they are found north, northeast and east† of the outcrops of the formation under discussion in parishes already mentioned, and to the south the Mansfield in Natchitoches parish dips under the Lower Claiborne at Victoria. The opinion has been expressed that the beds bearing marine fossils, found in the vicinity of Victoria, Provencal, Natchitoches, St. Maurice, etc., are stratigraphically above the fossiliferous beds found in Bossier, Webster, Claiborne and Bienville parishes.

West of the outcrops of the Mansfield in Texas,‡ according to L. C. Johnson, is Claiborne. As the topography of the Mansfield does not represent a basin,§ such as would suggest

*Johnson. Iron Region of La. and Texas, p. 21. 1888.

†The Lower Claiborne is east of the Mansfield in Natchitoches, Winn and Grant parishes.

‡Iron Regions, La. and Texas: see map.

§The average altitude along the T. & P. railway, from Shreveport, after passing out of the river bottom, to Provencal, is 281 feet; along the V., S. & P. railroad from Shreveport, after leaving the Red river bottom,

that the Lower Claiborne had been eroded off and the Lignitic exposed, it seems to the writer that the Mansfield is only a portion of the Lower Claiborne devoid of marine fossils.

As the correlation in this paper is based on paleontological grounds, the following list of some of the more common fossils is given.

Cylichna galba Con.
Borsonia biconica White.
Ancilla staminea Con.
ancillops Heilprin.
Monoptygma crassiplica Con.
Marginella larvata Con.
constrictoides Mey. & Ald.
Fusus mortoniopsis Gabb.
Papillina dumosa Con.
Pyrula (Fusoficula) texana Ald. and Harris.
Latirus moorei Gabb.
Pseudoliva vestusta Con.
Cornulina armigera Con.
Phos texanus Gabb.
scalatus Heilprin.
Murex engonatus Con.
Murex (Odontopolys) compsorhytis Gabb.
Distorsio septemdentata Gabb.
Cassis (Phalium) globosa Dall.
Cypraea kennedyi Harris.
Calyptraphorus velatus Con.
Rimella laqueata Con.
texana Harris.
Turritella vetusta Con.
nasuta Gabb.
dutexana Harris.
pleboides, sp. nov.
Natica semilunata Lea.
Lunatia eminula Con.
Neverita limula Con.
Liotia granulata Lea.
Ostrea divaricata Lea.
alabamiensis Lea.
sellæformis Con.
Anomia ephippoides Gabb.
Pecten claibornensis Con.
Arca rhomboidella Lea.
Trigonarca decisa Con.
Limopsis aviculoides Con.
Venericardia planicosta Lam.
Meretrix poulsoni Con.
Corbula oniscus Con.
nasuta Con.
texana Gabb.
Protocardia gambrina Gabb.
Astarte tellinoides Con.
Pteropsis conradi Dana.
Flabellum cuneiforme Lons., var. pachyphyllum, G. and H.
Discotrochus orbignianus Ed. and Haime.
Platytrochus sp.
Turbinolia pharetra Lea.
Endopachys maclurii Lea., and many other species.

Except the above mentioned corals, all the corals are new species; but they are, with very few exceptions, identical with the species found in the Lower Claiborne of Alabama and Mississippi.

The presence of such mollusks as *Ostrea divaricata*, *O. sellæformis*, *Anomia ephippoides*, *Borsonia biconica*, *Latirus moorei*, *Fusus mortoniopsis*, etc., leaves no doubt as to what the homotaxial equivalents in Mississipi, Alabama, and Texas

to Calhoun, it is 247 feet. These elevations are taken from the respective railroad profiles.

are.* The corals are, if possible, even more decisive than the mollusks; but as only a few of the species have been described, their names are not cited, although I have manuscript descriptions of them and have had figures of them drawn.

The age of these beds has already been pointed out by Johnson,† Lerch,‡ and Harris,§ but all three have erred in making the Lower Claiborne area too small, and the Jackson area too large.

Lower Claiborne fossils were collected by the Louisiana Geological Survey at Georgetown, on the railroad from Monroe to Alexandria, near Little river. This shows the existence of Lower Claiborne strata farther south than has hitherto been recorded. Some of the species are:

Volutilithes petrosus Con.	Scalaria nassula Con.
Latirus moorei Gabb.	Venericardia planicosta Con.
Lunatia eminula Con.	Corbula sp.

I regard the *Latirus moorei* as indicative of the age of the beds.

Four questions need further discussion: 1st, the Arcadia clays; 2d, the small prairies or meadows in Bienville, northern Winn, and Natchitoches parishes; 3d, the "Upper Lignitic" of Dr. Lerch; 4th, the red clays in the vicinity of Mt. Lebanon and Arcadia.

The Arcadia clays. Dr. Lerch has described in both Part I and Part II of his "Report on the Geology of the Hills of Louisiana," a series of gray clays, typically exposed in the vicinity of Arcadia, and which he considered as resting upon the eroded surface of the Claiborne strata. To these clays in

*The attention of the reader is called especially to the following publications:

Wm. M. Gabb: Jour. Acad. Nat. Sci. Phila., new ser., vol. IV, p. 376 et seq., 1860.

T. H. Aldrich and O. Meyer: Journ. Cinn. Soc. Nat. Hist., vol. IX. No. 2, pp. 40-50, 1886.

T. H. Aldrich: Prelim. Rep. on the Tert. Foss. of Ala. and Miss.. Bull. 1, Ala. Geol. Surv., 1886.

A. Heilprin: Proceed. Acad. Nat. Sci. Phila., 1890, p. 393 et seq.

G. D. Harris, Tert. Geol. of Southern Ark., Ark. Geol. Surv., Report State Geologist for 1892, vol. II, 1894.

E. T. Dumble: Journ. Geol., vol II, No. 6, 1894, pp. 551-555, 566.

Wm. Kennedy: 2d, 3d and 4th Ann. Reports, State Geologist of Texas.

† Iron Regions of La. and Texas, p. 20, 1888.

‡ Part II, Geol. Hills of La., p. 82, 1893.

§ Tertiary Geol. S. Ark., p. 177, 1894. Prof. Harris erred in accepting the previous work of Johnson on the areal distribution.

his second report the name "Arcadia clays" was given, and they were considered of Jackson age.

The author was first led to doubt the existence of an unconformity for paleontologic reasons. The Lower Claiborne attains a fine development in Louisiana. In Winn and Natchitoches parishes, the Lower Claiborne beds, as already noted, become very calcareous, and *Ostrea sellæformis* is often found in the greatest abundance. These features are characteristic of Hilgard's *Calcareous Claiborne* in Mississippi, which has been correlated with the *Ostrea sellæformis* beds of Alabama by Smith. The *Ostrea sellæformis* beds in Alabama are separated from the Jackson by scarcely 30 feet of strata. Whether the calcareous beds of Winn and Natchitoches parishes are the exact equivalent of the *Ostrea sellæformis* beds of Alabama or not, the fact remains that they are not far from the base of the Jackson, and it seems improbable that a long period of dry land surface could have intervened. Furthermore, G. D. Harris* in Arkansas discovered beds "Uppermost Clailornian or perhaps transitional between that and the Jackson," a fact to my mind making it still more improbable that there could have been in Louisiana an erosion period between the two stages.

In order to study this supposed unconformity further, in November, 1894, I went to Arcadia to examine again some sections in that vicinity. Fig. 3, plate IX, represents a section made in the first railroad cut west of that town. The gray or Arcadia clays were found resting conformably on the black clays. The dip of both the gray and black clays was the same both in direction and amount, and the stratification was absolutely continuous from one clay to the other. From the distribution of the color one would at first be inclined to think that there was an unconformity, but in a layer not thicker than one's finger I have seen the stratum in the length of about a foot, light gray or blue, then chocolate, and at last black (or almost black) where it passes into the lignitic nucleus of the cut. Fig. 4, a section made on the La. & N. W. railway, six and a half miles south of Gibbsland, represents the same phenomena. Instead of an unconformity, I would suggest as an explanation, that the waters working

*Tertiary Geology of Southern Arkansas, p. 93, 1894.

along the sides of the hill have leached out some of the coloring matter of the black clays and have thus produced the appearance that the hills now present, viz.: a black nucleus mantled by gray clays. It has been suggested to me, to call the black clays an *unweathered nucleus*. In some cases the difference between the gray and blackish clays may be due to different lithologic constitution, but I have never seen any evidence of an erosion period intervening between the "Arcadia clays" and the Lower Claiborne beds.

On only one of the hilltops above the "Arcadia clays" did I find fossils and that was on the La. & N. W. railway, between five and six miles south of Gibbsland. Here gray and mottled clays grade upward into red clays which contained a cast of *Venericardia planicosta;* as this species is found in both the Jackson and lower Eocene beds, it does not fix the age of these beds. But on Hammett's branch, S. W. ¼, Sec. 30, Twp. 18 N., R. 6 W., in a gray joint clay numerous Lower Claiborne fossils, such as *Anomia ephippoides* and *Flabellum cuneiforme* var. *pachyphyllum*, were found. On p. 11 of his first report, Dr. Lerch states: "A paucity of fossils characterizes these deposits, and so far only near the line of contact with the underlying green sand, marine shells have been found which prove to be the same as those found in the underlying Claiborne formation."

I believe that the name "Arcadia clays" must be abandoned and the clays for which the name stands be referred to the Lower Claiborne.

*The Small Prairies of Winn and Natchitoches Parishes.** Unfortunately, from lithologic and topographic resemblance, much of the Lower Claiborne of Louisiana has been confused with the Jackson. Johnson states on p. 16 of his report on the "Iron Regions of Louisiana and Texas": "The boundary of this formation [the Jackson] was traced by prairies and wells along the left bank of Bayou Saline and from the S. W. ¼ of Sec. 20, T. 16 N., R. 5 W., northeastward to Gansville, near the borders of Jackson and Winn parishes, and runs diagonally through Jackson parish in the direction of Monroe,

*Until the author had studied the fossils found in these prairies, he thought some of the Lower Claiborne was Jackson.

Ouachita parish. The formation probably occupies high points till farther north on Bayou Saline."

Dr. Lerch, on p. 89 of his second report, gives a section in White Oak Creek ten miles northwest of Winnfield, which he considers to be the contact between the Jackson and his Upper Lignitic. He states: *"A similar section is seen in No. 7 (fig.) of foregoing pages. The characteristic bald prairies are abundant in the neighborhood, and in the dumps of wells with undrinkable water large selenite crystals and Jackson fossils have been collected."

Both of these gentlemen have erred as to the age of these beds, as the following list of some of the more characteristic fossils from one of these prairies ten miles northwest of Winnfield will show. This collection was made by the Louisiana Geological Survey and was submitted to the author for study. My thanks are due to Prof. G. D. Harris for assistance in determining some of the mollusks.

Fusus mortoniopsis GABB.
Pseudoliva vetusta CON.
Cassidaria planotecta MEY. and ALD.
Rimella texana HARRIS.
Turritella apita DE GREG.
 dutexana HARRIS.
Calyptraea trochiformis LAM.
Dentalium minutistriatum GABB.
Ostrea divaricata LEA.
 alabamiensis LEA.
Pecten claibornensis CON.
Limopsis aviculoides CON.
Crassatella texalta HARRIS.
Corbula oniscus CON.
Protocardia gambrina GABB.
Two undescribed corals, both typically Lower Claiborne, to which I have given the names *Flabellum lerchi* and *Paracyathus bellus*.

There is not a characteristic Jackson fossil in the above assemblage, while many are strictly Lower Claiborne.

Limestone of similar character to that in which the above fossils occur as casts, and containing the same fossils, is found in Natchitoches parish, between Provencal and Robertsville, and one and a quarter miles south of Provencal.

In the vicinity of Victoria, Provencal, Natchitoches, and in southern Bienville parish, are beds of *Ostrea sellæformis*, which usually form small prairies. Unfortunately Dr. Lerch has been confused by this oyster; so I shall venture a correction. On p. 90 of his second report, in discussing the Jackson-Vicksburg groups, section No. 14 he states:

*The section was made on White Oak creek, Sec. 14, T. 11 N., R. 5 W.

About one mile* southwest of Victoria the following section was observed, showing well the position of the limestone of this formation:

1. Red sandy clays.
2. Limestone with Ostrea, 2 feet.
3. Gray clay.
4. Laminated black lignitic shales with sand partings to base.

The foregoing exposure is 100 feet in vertical height. As this is the last section northward along this line, we refer the above limestone to the Jackson beds till the fossils have been studied.

In last November I visited the locality in which this section was made, and found the limestone composed of *Ostrea sellæformis* and *Anomia ephippoides*, which of course put it into the Lower Claiborne; and as the gray clays are conformably just below the limestone, they must also be referred to the Lower Claiborne.

The "Upper Lignitic" of Dr. Lerch. This author has described a series of lignitic clays which he states overlie his "Marine Claiborne," and to which he has given the name of "Upper Lignitic." Part of his Upper Lignitic, as exposed ten miles northwest of Winnfield, undoubtedly belongs in the Lower Claiborne, for it is there overlaid by strata bearing Lower Claiborne fossils. But I am not certain that the strata in other localities presenting the same lithological appearance and designated by Dr. Lerch as the Upper Lignitic, occupy the same stratigraphic position. At Columbia the lignitic strata probably are not Lower Claiborne but represent what I have called the Cocksfield Ferry beds. The lignitic strata about three miles south of Rosefield† lie at the base of the Vicksburg, and most probably they are intermediate between the Jackson and that stage.

The red clays and red sandy clays in the vicinity of Mt. Lebanon and Arcadia. In northern Louisiana many hills are capped by deposits of red sandy clays, which in the vicinity of Mt. Lebanon, Homer, and Arcadia contain fossils that are, excepting one species, identical with those of the underlying Lower Claiborne. The exception is a new *Cardium*, to which I have given the name of *C. harrisi*. The species found in these deposits are:

---

*Not so far, scarcely ¼ mile.

†Lerch, Geol. Hills, La., Part II, p. 98, 1893.

Volutilithes petrosus Con.
Ostrea divaricata Lea.
Venericardia planicosta Lam.
Cardium harrisi, sp. nov.*
Pteropsis conradi Dana.

In many places in northern Louisiana the red sandy clays or sands rest unconformably on the Eocene, and doubtless belong to the Lafayette of McGee.

As it appears to the author that there has been some confusion of "Lafayette," "Orange sand," etc., with residual deposits, he gives at some length the reasons why he considers the superficial clays around Mt. Lebanon and Arcadia residual.

Two hypotheses for the presence of the Lower Claiborne fossils in the superficial deposits under discussion present themselves: 1st, they may have been transported; 2d, they may be in place. The latter hypothesis we regard as the correct one for the following reasons.

1. In Mt. Lebanon, and north and east of that place, many of these fossils are found as casts in ferruginous sandstone or as ferruginous replacements. One mile north of Mt. Lebanon, in a well from a yellowish sand many Lower Claiborne fossils were collected. In Mt. Lebanon Lower Claiborne fossils were found in greenish clays or sands thrown out of a well. Sections in these wells and the vicinity show that superficial strata rest directly upon the subjacent Eocene.

2. The transition from the Eocene to the superficial deposits can be traced. In fig. 2, plate IX, the glauconitic sands pass by oxidation into the yellow sands, and the yellow clay passes by oxidation into the red. The yellow clay has frequently on its surface blotches of red which have been produced by oxidation. The transition from the Eocene to the surface red clays is seen at Arcadia, six and a half miles south of Gibbsland on the La. & N. W. railroad, and between five and six miles south of Gibbsland on the same road. At the latter place in the red clay *Venericardia planicosta* was found, as already noted.

3. Fossils found in the well one mile north of Mt. Lebanon, imbedded in indurated glauconitic sand, are so similar in oc-

*Mr. Harris has examined the specimens submitted to me, and writes me that he found the same species at Walnut Bluff, Ouachita river, Arkansas. On page 142 of his Arkansas report, the species is referred to as *Cardium* sp.

currence to those in the red sandy clays as to suggest that, were the sands further oxidized and the calcareous shells dissolved out, there would result exactly what is found in the surface sands.

4. There are in the specimens from the superficial deposits no indications of their having been waterworn. In *Cardium harrisi* the angles are very sharp, so that if it had been transported it must have been imbedded in rock. As the specimen is large, a powerful current would have been required and there are no indications of such.

For the above reasons the author considers the red clays and red sandy clays on the hills in the vicinity of Mt. Lebanon and Arcadia as oxidized Eocene.

Fossils as casts in ferruginous sandstone have been found in Lincoln, Claiborne, and Bossier parishes.

The Cocksfield Ferry beds.

Conformably above the fossiliferous Lower Claiborne at St. Maurice, fig. 6, plate IX, are laminated non-fossiliferous clays or laminated sand and clay, dipping slightly south. These beds present different lithological phases, sometimes containing more clay and little or no sand.

The same beds are well exposed at Cocksfield Ferry, about halfway between St. Maurice and Montgomery, fig. 7, plate IX.

At Montgomery, immediately below the Jackson,* beds lithologically like those found in the upper part of the St. Maurice section and like those at Cocksfield Ferry are found. The section at Montgomery is represented in fig. 8, plate IX. The dip at Montgomery is somewhat steeper than at St. Maurice.

For these beds between St. Maurice and Montgomery, coming between the Lower Claiborne and the Jackson, I propose the local name of *Cocksfield Ferry beds.* In a general way they represent the Claiborne sands of Alabama, but it is not possible to limit precisely the Lower Claiborne above or the Jackson below, and one cannot state exactly how much or what part of these beds represent the Claiborne sands. No beds bearing marine fossils and equivalent to the latter beds have been found in Louisiana.

*Dr. Hilgard notes lignitic beds beneath the Jackson in Mississippi. Agric. and Geol. Miss., pp. 108, 123, 127, 128.

The Jackson and Vicksburg stages.

As pointed out by Dr. Lerch in his report on "Geology of the Hills of Louisiana," the Jackson and Vicksburg pass conformably into each other and resemble each other so closely lithologically that they can be distinguished only by paleontologic characters. Both stages are largely characterized by calcareous clays. At the base of the Vicksburg are lignitic strata, as can be seen in the section about three miles south of Rosefield in Catahoula parish. Dr. Hilgard* has noted a similar occurrence of lignitic clays and lignite at the base of the Vicksburg at Vicksburg and north of Brandon in Mississippi. On account of the lithological similarities of these two stages the area occupied by them must for the present be treated as a unit. On the north the area is limited by the Claiborne series of beds, the known Jackson outcrops being at Montgomery on the Red river, at Tullos and two miles north of Rosefield in Catahoula parish, at Bunker Hill in Caldwell parish, and at Grand View on the Ouachita river.

Mr. Harris, in his "Report on the Tertiary Geology of Arkansas," on p. 182 states: "The exact point at which the Jackson stage reaches the Ouachita river is still unknown. In 1834 Dr. Harlan described the genus *Basilosaurus* (*Zeuglodon*) before the American Philosophical Society, giving as its locality a point on the Ouachita river, fifty miles by land below Monroe. This means doubtless a locality not far from Grand View."

Hopkins† makes no reference to Harlan's work, and from his statement, even giving a section, I am certain that he had been to Grand View. By the crooked road south from Monroe, Grand View is very near the locality referred to by Harlan. I have Jackson fossils, submitted to me by the Louisiana Geological Survey, that came from two miles north of Rosefield, a point about five miles southwest of Grand View. Hopkins mentions Zeuglodon bones having been found "where the Harrisonburg and Columbia road crosses the Catahoula and Caldwell parish line."‡ This place corresponds very

*Agriculture and Geol. of Miss., p. 108, 1860.

†First Rep. La. Geol. Surv. for 1869, pub. 1870, p. 90.

‡Op. cit., p. 92.

closely with that whence the Louisiana Survey fossils that I have were obtained.

Mr. Harris further states: "Dr. E. W. Hilgard* has interpreted Harlan's locality for Zeuglodon remains as 'about half way between Columbia and Monroe.' It is very difficult to see how this construction can be put on Harlan's statement." I agree with Mr. Harris, and think Dr. Hilgard made a *lapsus pennæ*.

North of the line indicated by the above localities for Jackson fossils, none have so far been reported by competent paleontologists.

West of the Red river so far not a Jackson fossil has been authoritatively reported.† When at Provencal in November I drove eight miles south of that place searching for Jackson outcrops. In the banks of Santa Barba creek (called by the inhabitants Sandy Burg) I found a greenish blue clay containing calcareous nodules, resembling considerably in lithologic appearance the Jackson at Montgomery. The river has a wide valley opposite Montgomery, so Dr. Lerch had no chance to find Jackson fossils while making his section along the T. & P. railway from Alexandria to Mansfield. Along the Claiborne-Jackson contact the Sparta sands obscure the older geology.

One point on the northern boundary needs a little further discussion. At Georgetown, in the valley of the Little river, Lower Claiborne fossils were obtained from a well. Jackson fossils, *Zeuglodon*, were found in a railroad cutting at Tullos, a few miles east of Little river. It is the opinion of the author that the stream has eroded away the Jackson and has thus brought the Lower Claiborne near to the surface.

The southern boundary of the Jackson-Vicksburg has been very well traced by Hopkins from the Ouachita to the Red river. The parting runs from a point two miles south of

*Geol. Reconn. La., p. 8, 1869.

† At Sabinetown, Texas, on the Sabine river, Hilgard on p. 20 of his Sup. and Fin. Rep. of a Geol. Reconn. of La., mentions having found Jackson fossils. Mr. E. T. Dumble, in vol. II, No. 6, of the Journal of Geology, on p. 566, referring to the Eocene of Texas, writes: "None of the beds of the Eocene having yielded fossils characteristic of horizons higher than the Lower Claiborne, the deposits referable to that series are confined to its basal portion." On a map of the Eocene of eastern Texas, by W. Kennedy, the beds at Sabinetown are represented as *Marine beds*, which are, according to Mr. Dumble, Lower Claiborne.

Rosefield, near Centreville, crosses Little river five miles below Georgetown and reaches the Red river five miles north of Colfax.

Some of the fossils found in the Jackson of Louisiana are:

Zeuglodon.
Umbrella planulata CON.
Conus tortilis CON.
Conorbis alatoides ALD.
Cassidaria petersoni CON.
Turritella alveata CON.
Xenophora reclusa CON.
Amalthea americana CON.
Natica permunda CON.
Ostrea trigonalis CON.
Pecten nuperus CON.
Pectenculus filosus CON.
Venericardia planicosta LAM.
jacksonensis CON.
Crassatella flexura CON.
Corbula bicarinata CON.
Flebellum cuneiforme LONS., var. wailesii CON.
Trochocyathus lunulitiformis CON., and many others.

Fossils of the Vicksburg stage were collected at only one locality by the Louisiana Geological Survey, viz., three miles south of Rosefield.

Some of the fossils found here were:

Dentalium mississippiense CON.
Ostrea vicksburgensis CON.
Pecten poulsoni MORTON.
Arca mississippiensis CON.
Byssoarca lima CON.
Pectunculus arctatus CON.
Crassatella mississippiensis CON.
Meretrix sobrina CON.
Eupsammia caulifera CON.
Orbitoides mantelli MORTON.

In the American Journal of Science, 2d ser., vol. XLVIII, 1869, p. 340, Dr. Hilgard mentions *Orbitoides*, *Pecten poulsoni*, and *Ostrea vicksburgensis*, from the heads of Bear creek between Dugdemona bayou and the Red river. On p. 33 of his "Supplemental and Final Report of a Geological Reconnoissance of Louisiana," he refers to this same locality as "seven miles (west) from Little River Ferry."

In the American Journal of Science, 3d ser., vol. XXX, 1885, p. 269, the same writer mentions *Orbitoides*, *Arca mississippiensis*, and *Pecten poulsoni*, from Bayou Funne Louis.

We possess the following data regarding Vicksburg rocks west of Red river. Dr. Hilgard states in the American Journal of Science, 2d ser., vol. XLVIII, 1869, p. 339, "At the base of the Grand Gulf rocks we find, on bayou Taureau, a seam of shell limestone with Vicksburg fossils." On page 19 of his Supplemental and Final Report of a Geological Reconnoissance of Louisiana, he mentions *Arca mississippiensis* from this locality.

MIOCENE: THE GRAND GULF GROUP.

The Miocene of Louisiana is represented by the Grand Gulf group of Hilgard. These rocks have been described by Hilgard, Hopkins, Johnson, and Lerch.

They are composed of clays, sands, claystones, sandstones, and quartzites. So far no fossils have been collected and determined from them, but they are referred to the Lower Miocene because they are without doubt the same as the Grand Gulf of Mississippi, the age of which has been fixed positively.*

The northern boundary of the Grand Gulf has already in part been indicated in this paper. It runs north from Harrisonburg, flanking the bottom of Ouachita river, to a point about three miles south of Rosefield. The line from this point to the Red river has already been indicated. West of the Red river there are excellent exposures at Chopin. Thence the line has been traced to the Sabine river by Hopkins. After crossing the Red river Hopkins says: "Reäppearing in the Cloutierville and Kisatchie Hills, it ranges almost due west to the 'Bad Hill' seven miles south of Many, in De Soto, and reaches Sabine, near the mouth of Bayou Negrut."†

The relation of the Grand Gulf to the Eocene is a perplexing question, and is one not satisfactorily settled. Pumpelly‡ and Dall§ have shown that in Florida the lowest Miocene rests unconformably on the Vicksburg Eocene. We have in Louisiana the Vicksburg Eocene and the Lower Miocene.

The topographic features of the Grand Gulf are interesting. The northern boundary is, when not covered by the subsequent deposits, a rather steep escarpment facing inland, underneath which the Vicksburg dips. Dr. Lerch has given an excellent description of the topographic features of the Grand Gulf.

More than any of the previous regions described, it has the plain structure preserved, though erosion has been in this territory not less active it has chiseled out different forms. Instead of the well rounded hills and more gentle slopes of the ridges occupying the region north of its boundary, it slopes from its deeply dentated and broken north line

*Dall, Bull. Geol. Soc. Amer., vol. v, 1894, pp. 164, 167.
Smith. Am. Jour. Sci., III, vol. XLVII, p. 296, April, 1894.
Smith, Chart to Geol. Map of Ala., 1894.

†Hopkins: First Ann. Rep., Geol. Surv. La. for 1869, pub. 1870, p. 99.

‡Amer. Jour. Sci., III, vol. XLVI, p. 445 et seq., 1893.

§Bulletin Geol. Soc. Am., vol. v, p. 162, 1894.

southward under a steep angle beyond the boundary of the present survey, rapidly towards the gulf, presenting a plateau in which the rivers have cut wide valleys with steep walls and their tributaries, narrow gulleys with broken and dentated embankments, several over 100 feet in height. Frequently the country roads wind along a narrow ridge, falling steep to either side for many miles through this section. The features of erosion resemble somewhat the country north of it where the drift sands have accumulated, forming sections almost equally steep. They lessen in height in a southerly direction. The landscape these rocks offer is very monotonous. The open woods of the long leaf pine, as far as the eye can reach, and the green turf interrupted by bare spots of the gray sands derived from the underlying sandstones sometimes cropping out in high knolls along the road, or from the sands and gravels of the drift which generally cover the rocks of this formation in a thin sheet. The waters of streams and creeks are swift, rich in fish, especially trout and perch, and almost of crystalline clearness, unless they wind along a swampy bottom, and springs are even more numerous than in the northern part of the State.*

AGE UNDETERMINED: SPARTA SANDS.†

Extending across the central portion of Louisiana are deep quartz sands. The northern extent of these sands is as follows: They reach to T. 16 N., on the Louisiana meridian; the boundary from there passes two miles south of Gansville, thence northwest to Sparta. From Sparta it runs south to the northwest corner of Natchitoches parish, and thence the boundary is formed by Black Lake bayou and Black lake, to the mouth of that lake. West of the Red river the line runs from Victoria by Fort Jessup and south to the mouth of Bayou Toreau.‡ Except a narrow strip along the Ouachita river, nearly all of the region between the fluviatile deposits of the Red and Ouachita rivers is covered by these sands. I have not examined the southern boundary west of the Red river. These sands overlap both the Lower Claiborne and the Grand Gulf, extending entirely across the Jackson and Vicksburg.

The material of these deposits is usually almost pure quartz

---

*Prel. Rep., Geol. Hills of La., Part II, pp. 93, 94, 1893.

†These sands and gravels have been called drift by Hopkins and Lerch. In order not to venture an opinion as to their age, and not to attempt a correlation of all the superficial upland sands and gravels of northwestern Louisiana, I have proposed a local name, and desire to include under it deposits of whose homogeny and contemporaneity there can be no reasonable doubt.

‡See Lockett's Topograph. Map of La., 1882. I have seen this line all through the territory except along Black Lake bayou and Black lake, and from Victoria to the Sabine river.

sands, sometimes with reddish coloring matter, but in Grant parish there is a great deal of quartz gravel. In the southern gravelly portion transported fossils have been found.*

The topography of this formation is interesting. The rocks are easily eroded, and the hills rise very steeply to a hight of 75 to 100 feet above their bases, They are clothed with a forest of long-leaf pines (*P. palustris*), between which there is no undergrowth, so that when one stands on a hilltop his view is only obstructed by the multiplication of trunks in the distance. The whole area is covered with these trees, except in a few places where the Lower Claiborne, Jackson, or Vicksburg forms small calcareous prairies, and in the "hollows" between the hills. It is a magnificent lumber region.

The sands and gravel of this formation range in thickness from a trifling veneer to 60 and sometimes to 100 feet. Along the contact with the Eocene, as seen near Provençal, there is some clay at the base (see fig. 9, plate IX). These deposits rest with a distinct unconformity upon the older rocks.

For these sands and gravel the name *Sparta sands* is proposed, because they are well developed near that town.†

The Gravels between Daucheat and Black Lake bayous and west of Black Lake bayou. Occupying the divide between Daucheat and Black Lake bayous, and forming the banks of Daucheat in many places, are gravel deposits to which several writers have made reference. They are also found west of the Black Lake bayou at Taylor on the V. S. & P. railroad. They can be traced south, and, from what I have seen in southern Bienville parish, I am inclined to think that they pass into the Sparta sands. Dr. Otto Lerch‡ has described a similar gravel deposit accompanying the Ouachita river.

Sands at Mansfield. Overlying the Eocene at Mansfield are white sands§ with small bits of white clay intermingled. Near Burk Place in Bienville parish, I have seen angular bits of white clay in the lower part of a section of the Sparta sands. I do not attempt to correlate the sands at Mansfield, but call attention to this similarity to the Sparta sands.

*Lerch, Prel. Rep. Geol. Hills of La., Part II, p. 104, 1893.

†Sparta is in central Bienville parish.

‡Part I, Geol. Hills La., p. 25, 1892; Part II, p. 103, 1893.

§McGee, in his map of the United States published in Johnson's Encyclopaedia, represents these sands as Neocene.

Pleistocene and Recent.

THE SECOND BOTTOMS AND ALLUVIAL VALLEYS.

Lower topographically than the Sparta sands, accompanying the larger streams. are broad flats which occupy an elevation considerably higher than the present alluvial valleys. These flats are especially noticeable along the Red and Ouachita rivers. They have been well described by Dr. Lerch.

Later than the Second Bottoms and occupying a lower topographic level are the present alluvial valleys.

The Section of Northwestern Louisiana.

The following is the section presented by northwestern Louisiana, as I have made it out:

Recent		Alluvium.
Pleistocene		Second bottoms.
Age undetermined		Sparta sands.
Tertiary	Miocene	Grand Gulf group.
	Eocene	Vicksburg stage.
		Jackson stage.
		Cocksfield Ferry beds.
		Lower Claiborne stage.
		Lignitic stage.
Cretaceous		Glauconitic division.

I have not given estimates of the thickness of the Eocene, because the dip is too slight and variable to furnish reliable data, and no records of borings are available.

Summary of Conclusions.

1. The Cretaceous of Louisiana belongs to the Glauconitic division, and it seems probable that its deposition was followed by an erosion period.

2. (a) In Louisiana we find strata probably representing the Lignitic of Alabama in the extreme northwestern corner and at Shreveport.

(b) The Claiborne of Louisiana, bearing marine fossils, represents the Lower Claiborne stage of Alabama, and it occupies a more extensive area than has hitherto been recognized. In the southern part of the area the beds are much more calcareous than in the northern and northwestern part. The calcareous strata are probably stratigraphically above the more glauconitic beds to the north and northwest.

(c) The Mansfield group of Hilgard,

(d) Dr. Lerch's "Arcadia clays."

(e) and the small prairies or meadows in southern Bienville, northern Winn and Natchitoches parishes, are Lower Claiborne in age.

(f) The "Upper Lignitic" of Dr. Lerch represents beds belonging to two or more different horizons.

(g) The red clays and red sandy clays in the vicinity of Mt. Lebanon and Arcadia are Lower Claiborne in age.

3. Intervening between the Lower Claiborne and Jackson, are lignitiferous sands and clays, here called the *Cocksfield Ferry beds*, which in a general way represent the Claiborne sands of Alabama.

4. The Jackson and Vicksburg stages form a strip of territory between the Red and Ouachita rivers. They resemble each other in lithologic characters so closely that they can be distinguished only by their fossils. Apparently coming between the two stages is a lignitic bed such as is found in Mississippi. West of the Red river Jackson fossils have not been authoritatively reported.

5. The Grand Gulf of Louisiana is Lower Miocene. Its relations to the Vicksburg are not known.

6. Covering the southern part of the Lower Claiborne area and all of the Jackson and Vicksburg, excepting small spots, and extending over the Grand Gulf, are deep quartz sands, sometimes with gravel, which bear a growth of long-leaf pine. These sands rest unconformably on the lower terranes. The name *Sparta sands* is proposed for them.

7. Accompanying the larger streams, occupying lower levels than the Sparta sands, are wide second bottoms. Topographically still lower are the present alluvial valleys.

EXPLANATION OF PLATE IX.

FIG. 1. Section at Slaughter Pen bluff, at the head of Cross lake, one-half mile above Shreveport. (Reduced from figure in L. C. Johnson's Iron Regions of Louisiana and Texas, p. 18.) This section probably is Lignitic.

FIG. 2. Section of Lower Claiborne on Hammett's branch, S. W. ¼ Sec. 30, T. 18 N., R. 6 W., two miles northeast of Mt. Lebanon. No. 1 grades into 2, and 5 is derived from 6 by oxidation.

FIG. 3. Section of Lower Claiborne in the first railroad cutting west of Arcadia. Length of cutting 1,040 feet; depth, 15 feet.

1. Red clay with some sand passing into
2. Gray laminated clay ("Arcadia clays"), passing into

3. Black thinly laminated clay.

FIG. 4. Section of Lower Claiborne 6¼ miles south of Gibbsland on the La. & N. W. railway. Length of cutting 510 feet: depth, 16¼ feet.

1. Red clay, with some sand in the upper portion, passing into
2. Gray laminated clay ("Arcadia clays"), passing into
3. Black thinly laminated clay.

FIG. 5. Section of lower Claiborne one-half mile north of Natchitoches on Old river. No. 1 is a yellow calcareous marl with calcareous nodules, forming a prairie soil. *Ostrea sellæformis* and an *Orbitulina*-like foraminifer are very abundant in many places on the surface. Below the surface a few feet, sometimes fossils are numerous, sometimes only calcareous nodules are present.

Below the lignite seam (3), the laminated sands and clays sometimes show cross-bedding.

FIG. 6. Section of bluff on Saline bayou one-half mile above St. Maurice, showing fossiliferous Lower Claiborne (4), overlaid by the Cocksfield Ferry beds (2). I do not know whether 3 should be referred to the same category as 4, or classed with 2. The whole section, excepting 1, is one conformable series. No. 1 is gravel, probably of Columbia age.

FIG. 7. Section at Cocksfield Ferry, showing the Cocksfield Ferry beds, lower part of section unexposed. No. 1 is gravel, probably of Columbia age.

FIG. 8. Section near the upper end of the bluff at Montgomery showing the Jackson 2, 3, and 4 overlying the Cocksfield Ferry beds 6 and 7.

FIG. 9. Section one-half mile west of Provencal on the T. & P. railway, showing what is probably the basal contact of the Sparta sands. Cutting 240 feet long, 9 feet deep.

1. Yellowish sand with some clays, resting unconformably on
2. Stratified red clay with white clay partings, mantled by soil, 2', probably Eocene.
3. Hæmatitic iron ore developed along the contact of 1 and 2.

[CRUCIAL POINTS IN THE GEOLOGY OF THE LAKE SUPERIOR REGION. NO. 2.]

THE PALEONTOLOGIC BASE OF THE TACONIC OR LOWER CAMBRIAN.

By N. H. WINCHELL, Minneapolis, Minn.

It was first in America that an effort was made to define the base of the Cambrian by faunal characters. From time to time lower and lower portions of the Cambrian strata were found to contain a characteristic trilobitic fauna, in Europe, and especially in Scandinavia, and without hesitation such strata were admitted into the Cambrian system. Barrande's

first definition of the primordial zone simply defined the "Paradoxides beds," which have since been found to be in the Middle Cambrian. Plainly the bottom of the Cambrian was not seen by him. In Wales Middle and Upper Cambrian faunas have been developed by Salter and Hicks, and by others, but no paleontologic base line has been found. Even the Olenellus zone has not there been discovered. This being the birth-place of the term, to which its later-discovered extensions must be referred for verification, the query might arise whether on paleontologic grounds the strata carrying Olenellus really belong to the Cambrian. However, the Olenellus strata have later been detected in Shropshire, bordering on Wales, and may reasonably be expected to extend into Wales. In northwestern Scotland also these strata are well developed, but seem to be succeeded directly by the upper (Olenus) beds, though no transgressive non-conformity between the Olenellus strata and the Olenus beds has been definitely established. The base of the Cambrian here presents a curious complexity. It is involved in a series of faults and thrust-fractures. The lowest rock which lies on the Archean unconformably is the Torridon quartzyte, as yet not proved to be fossiliferous, and non-conformably above it are found strata carrying the Olenellus fauna. The Torridonian quartzyte is from 8,000 to 10,000 feet thick. It had been included in the Cambrian,* notwithstanding the con-conformity at its summit, until the fucoid bed above the non-conformity was found to contain Olenellus, when it was immediately referred to the Pre-Cambrian. The profound non-conformity at the base of the Torridon quartzyte has a wide extension, and its significance has been remarked on by several English geologists. As a datum from which to begin the reckoning of Paleozoic time it holds first rank, and there ought to be some better reasons for excluding it from the Cambrian than the non-discovery of characteristic Cambrian fauna. In the Longmynd region, also, similar irregularities occur, but at this place the strata are broken by volcanic and other igneous interpositions. Some have claimed that even the Longmynd strata are Pre-Cambrian, i. e. Archean, because, apparently, Olenellus occurs above them, with evidence of volcanic disturbance between.

*A. GEIKIE. Quart. Jour. Geol. Soc., Aug., 1888, p. 400.

Throughout Britain, therefore, in late years, the paleontologic base of the Cambrian has been taken to be the Olenellus horizon, although evident clastic strata, long called Cambrian, occur widely below the Olenellus horizon.

It appears, from an examination of the literature bearing upon the Cambrian of Britain, that the time of the Cambrian was subject to volcanic outbreaks, as represented by A. Geikie and by Dr. Hicks. In some places this was the cause of significant variation in the nature of the sediments, as well as of changes of level of the land, causing the submergence of areas that had before been dry, and bringing the Paradoxides beds and later the Olenus beds non-conformable upon the Archean, and even upon older parts of the Cambrian. The principal disturbance of this nature seems to have taken place early in Cambrian time. Just at what epoch the Olenellus fauna was introduced, at the different places at which it has been discovered, there is as yet not sufficient evidence to affirm. It may be that the life of the Olenellus fauna was very long, and that when it was exterminated at one point, by volcanic conditions in the ocean, it continued to flourish at others, or that it returned again to its former habitat on the return of favorable conditions. Another principal event in the time of the Cambrian, in Britain, seems to have been that which separated the Olenus strata so markedly from the older portions of the Cambrian. This in some places brings the Olenus beds directly upon the Olenellus or pre-Olenellus strata.

In Scandinavia and the Baltic region the Cambrian formation is greatly reduced in thickness, and the Olenellus fauna is found near the base, which is marked by a striking nonconformity upon the gneissose Archean. There has not been, so far as observed, any proposition to separate the lowest of these strata from the Cambrian. The occurrence of Olenellus near the basal beds in Scandivavia, where the most evident succession of parts appears, and where the lower faunal changes were made out first with exactness, seems to have been the initial fact which inspired the idea of limiting the Cambrian with the Olenellus beds.

In the Salt range of India, according to recent work by

Fritz Noetling, the Cambrian consists of four parts, as follows, in descending order:

1. Bhaganwalla group, or salt crystal pseudomorph zone.
2. Jutana group, or magnesian sandstone.
3. Khussuk group, or Neobolus beds.
4. Khewra group, or purple sandstone.*

Olenellus here occurs near the top of No. 3, the Kussak group. Below it are found Neobolus warthi, Hyolithes wynni, with annelids and bivalves. According to the limitation that has assumed Olenellus as in the basal zone of the Cambrian, the whole of No. 4 and the most of No. 3 would be excluded from it.

In America the Paradoxides horizon was believed for several years to be at the bottom, even when Olenellus had been discovered, because the structural relations were not evident, and because both in Bohemia and in Britain Paradoxides only had, at that time, been found in the lowest fossiliferous strata. When this error was corrected for America, by Mr. Walcott, who visited Newfoundland and verified the Scandinavian order of faunal succession, the idea was at once assumed that the Scandinavian basal plane of the Cambrian should be taken generally as the Cambrian base line. This assumption has been popular with paleontologists. It gives a definite plane, from a biological point of view, but it ignores greater and more significant physical events which have separated the history of the globe into "times," and the rocks into systems. It also curtails the original definition of Cambrian, in the country of its nativity, for it has already led to the attempted assignment of a large part of the basal Cambrian to the pre-Cambrian, which is, in other words, Archean, although such beds are strikingly unlike any known Archean. Reference is here made to the Torridonian and to the Longmyndian.

The Taconic of New Brunswick has been very fully investigated by Matthew. In his summary conclusions† it appears that the Taconic is there divisible into four parts, the lowest being the Etcheminian, separable from the overlying portions by some kind of physical disturbance which left traces

*On the Cambrian formation of the eastern Salt range, Records Geol. Sur. India, vol. XXVII, pt. 3, pp. 71-86, 1894.

†Transactions of the Royal Society of Canada, 1893.

of a non-conformity at its summit. That part which first succeeds this plane is strongly paradoxidean, while the uppermost portion is broadly equivalent, paleontologically, to the Olenus horizon of Britain, or to the lower part of the St. Croix series of the upper Mississippi valley. In the whole series in New Brunswick no species of Olenellus is reported by Matthew, who is rather inclined to believe its position is held by the species of Paradoxides and other trilobites found in his "Division 1." It is possible, however, and perhaps probable that the horizon for Olenellus is to be sought for in the Etcheminian, and that the trace of non-conformity at the top of that group indicates, as in Europe, the cause of the change from Olenellus to Paradoxides, viz., volcanic disturbance. Whether Olenellus ever existed in New Brunswick or not, it is plain that a great series of clastic strata, nearly non-fossiliferous, there extends downward below the lowest trilobitic fossils, and that the whole has been included by Matthew in the Lower Cambrian. The thickness of this lowest part is 1,200 feet.

The Cambrian of Wales is the Taconic of America, even in the errors at first committed by the respective authors of these terms. The Taconic, however, has never been limited at the bottom except at the great plane of non-conformity which, as Sir Archibald Giekie shows, extends through the northern parts of Europe and North America, and which suddenly separates the crystalline Archean from the nearly horizontal clastics which lie upon it with "violent" non-conformity. As the histories of these formations are developed in geological literature they are shown to have a wonderful similarity. This is true not only as to the nature of the rocks of which they are composed, the fossils which they contain and the succession of events which make up the epochs of time represented, but in the progress of the investigations which have been carried on on opposite sides of the Atlantic. But the Taconic, from the first, has extended down to the "sedimentary base" which coincides with this great plane of non-conformity. It embraces, therefore, all the eruptive rocks which have their dates within Taconic time, whether they be ash-bed fragmentals or injected or eruptive traps. If it be in general the

parallel of the European Cambrian, it is highly probable that some of the eruptive rocks which have been found closely associated with the Cambrian in Wales and England are of so late a date that they fall within Cambrian time. These seem to be represented in the Taconic in America. The exact relation that they bear to the Olenellus horizon has been an American question with different views, as in Europe, but in America the earliest principal disturbance apparently followed this fauna, as will appear later.

The position of the Olenellus zone has been thus summarily defined by Van Hise:

> Placed in the Algonkian, under this definition [i. e. assuming the Olenellus zone as the base of the Cambrian. N. H. W.] are 11,000 feet of quartzytes conformably below the Olenellus in the Wasatch; 10,000 feet of argillytes, sandstones, quartzytes, and conglomerates conformably beneath the Olenellus in British Columbia; 12,000 feet of sandstones, shales and limestones uncomformably beneath the lowest known Cambrian in the Grand canyon of the Colorado: a similar series of rocks unconformably beneath the Cambrian in Llano county, Texas, a series unconformably beneath the upper Cambrian in the Adirondacks, and the rocks of St. Mary's and Placentia bays, Newfoundland, which are unconformably below Lower Cambrian strata. *Van Hise, Correlation Papers, p. 469.*

It is only intended by this brief review to call attention to the stratigraphic position of the Olenellus fauna in those portions of the globe where it has been most carefully determined. It certainly is a convenience from a paleontological standpoint to recognize definite faunal planes. It may be, therefore, an aid to the progress of geological research to refer to the plane of the Olenellus fauna as a marked and well established datum; and in the present state of stratigraphic paleontology such an assumption may serve a good purpose for a trial hypothesis; but it should be remembered that there are many lines yet to be followed out and many regions yet unexamined. The Paradoxides and the Olenellus faunas may be found to be closely related, and perhaps to blend, as suggested by Matthew. It should also be remembered that if it become agreed to limit the Cambrian at the Olenellus zone the underlying conformable clastic strata, down to the great non-conformity, are not excluded from the Taconic.

THE MISSOURI LEAD AND ZINC DEPOSITS.

By JAMES D. ROBERTSON, E. M., St. Louis, Mo.

NOTE. In the recently published transactions of the Bridgeport meeting of the American Institute of Mining Engineers is a paper by Mr. Arthur Winslow having the above title. This paper is itself based upon an exhaustive report on the lead and zinc deposits of Missouri prepared by Mr. Winslow, while state geologist, from work prosecuted during the last five years. In this work the writer assisted. The original report is very broad in scope, the design being to make it a work of reference on lead and zinc, with Missouri as a center; a work which would be of general utility to this important industry of the state. It thus contains brief descriptions of lead and zinc deposits in other countries, general statistical tables, descriptions of processes and other matter of wide bearing. The general geology of the mining areas is described in great fullness and their history and problems are treated. Interest is centered, however, in the ore deposits of the state, detailed descriptions of the numerous ore bodies are given and their structure, composition and origin are discussed in a comprehensive way. The recent papers of Posepny, Jenney and others have awakened renewed interest in these topics in general, and especially as affecting the deposits of the Mississippi valley; and the appearance of the report is hence very timely. The following paper is essentially an abstract of the general discussion of the lead and zinc deposits of Missouri as set forth in the report.

The lead and zinc deposits of Missouri have of recent years become of such importance as to cause that state to rank first in the production of zinc and lead ores. In the year ending June 30, 1893, there was produced 40,300 tons of lead ore and 108,600 tons of zinc ore. The year ending June 30, 1894, showed a production of 52,000 tons of lead ore and 89,150 tons of zinc ore, a decrease in the latter item but a decided increase in the former, in spite of hard times.

All of the deposits of lead and zinc are found in that portion of the state south of the Missouri river. Geographically and categorically the deposits fall into three districts. These are:

1. The southwestern district, comprising Jasper, Newton, McDonald, Barry, Lawrence, Dade, Greene, Webster. Christian, Taney, Stone and portions of Wright, Douglas and Ozark counties.

2. The southeastern district, comprising Franklin, Jefferson, St. Francois, Perry, Ste. Genevieve, Madison, Iron, Washington and portions of Crawford, Reynolds and Cape Girardeau counties.

3. The central district, composed of Cole, Moniteau, Morgan, Benton, Hickory, Camden, Miller and parts of Pulaski, Laclede, Maries, Osage and Pettis counties.

In the central and southeastern districts the rocks are mainly of the Ozark stage of the Lower Silurian, and in these rocks occur the ore deposits. In the southwestern district the

Lower Carboniferous rocks are the most abundant, and in these the principal ore deposits are to be found. In the eastern portion of this district, however, there are a number of deposits in the Ozark rocks. The age of the rocks of the Ozark stage has long been a mooted question. They were originally classed as the equivalent of the Calciferous rocks of the New York section and recent investigation goes to prove the correctness of this view.* The rocks consist in the main of magnesian limestones of varying texture, with intercalated beds of sandstone. Considerable chert is associated with them. The rocks of the Lower Carboniferous belong to what is generally known as the Burlington group, including, however, patches of Keokuk and rocks of the Kinderhook group. The ore deposits, however, are confined principally to the Burlington rocks. These consist mainly of fine, coarsely crystallized limestones, associated in places with beds of light colored, brittle chert, which are sometimes locally greatly developed, and occupy a large part of the section.

Structurally, the geology is quite simple. There is one master flexure expressed in the quaquaversal dip of the rocks from the Archean center. Beyond this there are a few minor flexures and also a few well marked faults. There are also a large number of minor faults and crevices unaccompanied by movement.

In the southwestern district the ore deposits are found almost wholly in the Lower Carboniferous rocks. In the central and southeastern districts they are confined entirely to the Lower Silurian. The deposits of the southwest are largely of zinc ore, while in the southeast lead is the principal ore mined.

The different districts are characterized by special forms of deposits. Thus, in the southwest the usual type is the massive. The ore body is frequently several hundred feet in diameter, consisting of ore and gangue and surrounded by a more or less barren limestone or chert bars. Stringers or sheets of ore may run out into the country rock, but these are not of sufficient size to affect the general form. In the eastern part of this district, tabular deposits in vertical crevices

*For the details of this investigation, the reader is referred to the Report on Lead and Zinc, Mo. Geol. Surv., Pt. I, pp. 378-385.

occur more frequently, although massive or cavern deposits are also found.

In the southeastern district we also have massive deposits, but the structure of the ore body is totally dissimilar to those just referred to. These consist of great masses of magnesian limestone in which the lead ore is disseminated in grains of varying size. As in the southwest, so in this district are found the tabular or sheet deposits, as well as lenticular and pipe deposits and stockwerke. These occur mainly in Jefferson, Washington and Franklin counties.

The ore body is composed of a mixture of gangue, ores and accessory minerals. The gangues consist of country rock, clays, sands and shales, secondary cherts and limestones, dolomite and barite.

The country rock is generally limestone, either pure or dolomitic, or chert. It occurs both massive and fragmental. The former is seen in the southeastern district, where the ore is disseminated through large bodies of massive magnesian limestone. In the southwest, the country rock is mainly fragmental and consists largely of chert breccia, although fragments of Coal Measure sandstone, shale and coal are met with in this breccia. The chert is angular, sometimes pitted, and while some blende or galena may occur in the crevices or cavities, these minerals are never found in any quantity through the rock. In the southeastern district, where the deposit occurs in portions of the Lower Silurian rocks close to the Archean floor, water-worn boulders of granite are met with. Clays of many varieties are found in these deposits. They are generally dark red in color, but also occur in all tints of red and yellow to pure white. Some of these lighter colored varieties are called "tallow clays," from their resemblance to tallow, and often contain a notable quantity of zinc. Sands resulting from the decomposition of cherts and quartzite occur in Jasper county and the adjoining Cherokee county, Kas. The shales consist of earthy sands and plastic and non-plastic clays which grade into sands on the one side and clays on the other. They are sometimes partly consolidated and sometimes soft and of the consistency of mud. Secondary cherts consisting mainly of an amorphous chalcedonic silica are abundant as gangues in Jasper and Newton counties and

at Galena, Kas., to which districts they are practically confined. They vary in color from white through all shades of drab and brown to black. They exhibit an equally wide range of texture, varying from a soft shale on the one hand, to a rock as hard and considerably tougher than quartz on the other. They frequently form the matrix of a breccia of angular chert fragments, which they hold with such tenacity that, in breaking, the line of fracture will pass through the chert fragment without even loosening it. At times the siliceous solutions appear to have partially dissolved the original chert fragments, thus causing the two to grade into one another. This silicification was evidently later than the deposition of the ores, as well-formed crystals of the galena and blende are frequently found enclosed in this matrix, and on being dissolved out leave perfect exterior casts. Secondary limestones occur in some deposits, but, so far as noticed, do not appear to be common. In specimens of such, the limestone forms the matrix of the chert breccia and often encloses crystals of blende. Dolomite, other than the magnesian limestones of the Ozark stage and of the pink crystals which are merely of mineralogical interest, is principally found in the southwestern district. It is usually composed of a dense though incoherent mass of gray, grayish white or drab dolomite crystals. It appears to have been formed by magnesian solutions acting on the limestones into which it often grades. Barite occurs as a gangue mineral in the southeastern and central districts. It is generally of the opaque white variety, tinged with iron on exposed surfaces. Vuggs occur in it lined with tabular crystals. It also occurs in some localities in limited quantities in large tabular, semi-transparent crystals, colorless or of a bluish tint.

The minerals include the zinc and lead compounds and the accessory minerals.

The zinc minerals are sphalerite, calamine, smithsonite and, rarely, hydrozincite. Sphalerite is found crystallized throughout the ore body and encrusting cavities. It is seen deposited on chert, limestone and dolomite. It is generally of a dark red color with a resinous luster, but is also found of a bright yellow color and often in small crystals of cinnamon and garnet colors. Calamine, locally known as "silicate," is found

mainly at Granby, Newton county, and at Aurora, Lawrence county. It is in the usual forms and there is little uncommon in its occurrence. It results from the decomposition of blende and coats crystals of that mineral as well as of calcite, and frequently forms pseudomorphs of the latter mineral. Smithsonite is likewise found in the usual forms and colors. It is the principal ore of zinc found in the southeastern district. In the trade it is known as "silicate" and is not distinguished from calamine.

Of the lead minerals, galenite is the most abundant and important. It occurs in cubes and cube-octohedrons in aggregates sometimes of large dimensions. In the southeast it is found in crystalline and crystallized aggregates associated with barite in the tabular and crevice deposits and in granular disseminated form in the magnesian limestones in the massive deposits. When deposited on calcite, barite, secondary chert or other gangue, the crystals are usually well developed; when found in the disseminated deposits the crystals are generally imperfect. All of the galena of this state contains a small quantity of silver, varying from ½ to 4 ounces per ton. Cerussite is found in all the districts, generally near the surface. It is nowhere abundant now, although it was previously mined in considerable quantities. Anglesite and pyromorphite are comparatively rare, and are of no commercial importance.

Calcite is found in a variety of forms, generally crystallized in the usual scalenohedral forms. Sometimes these crystals are found with the alternate angles rounded in a very peculiar way. Barite has been referred to before. It mainly occurs in the southeastern and central districts; only little is found in the southwestern district. It replaces fossils in the Lower Carboniferous limestone in Pettis county. Dolomite is abundant in the southwest but occurs sparingly as a mineral in the southeast. It is found in aggregates of small crystals, sometimes so incoherent as to form a sand. It also occurs in curved crystals of the usual shape, of a beautiful peach pink color. Pyrite and marcasite are found in all districts although the former is rather rare. Marcasite is comparatively common in the southwest. Chalcopyrite in small tetrahedrons is also frequently found. Quartz in the crystallized state is rare.

It has been seen in the southwest as a coating on galena and cerussite and blende. Drusy quartz, or "mineral blossom" is quite common in the southeast. There are a number of other minerals found in greater or smaller quantities of little but mineralogic interest: such are bitumen, malachite, azurite, limonite, goslarite, ferrogoslarite and melanterite.

The order of deposition of the minerals appears to be the following: dolomite, blende, galena, barite, pyrite, calcite. This order is not invariable, but is the one most commonly found.

In the southwest the deposits are usually characterized by a brecciated structure. This sometimes grades off insensibly into the country rock. Some of the crevice deposits in the southeast and central districts are brecciated in structure, as are also the circle deposits of the latter district. The massive deposits of the southeast are, however, characterized by a granular or crystalline structure. The dense structure is applicable to certain vein deposits in the central and southeast.

The general form of a southwestern massive ore deposit is a series of horizontal runs, which are ore bodies of an ill defined oblong shape, and which widen at places into large chambers, sometimes several hundred feet in diameter. The galena is almost invariably found over the zinc and is frequently in a somewhat soft clayey gangue mixed with broken chert, although it occurs also on chert and limestone. In some mines the gangue is composed entirely of original and secondary chert, with small amounts of dolomite or dolomitic sand, no limestone being visible in the roof, but only found in the barren bars. In other mines the gangue is principally limestone or dolomite and little or no chert is found. Still other deposits, notably those of Webb City, are opened under massive roofs of solid, barren limestone of considerable thickness, under which the ore is found in large chambers, occurring in the chert breccia and sometimes in Coal Measure shales.

In the southeastern district, the massive deposits consist of large bodies of the country rock which carry, in a more or less concentrated state, crystals or grains of galena. These rocks contain no chert, although a cherty limestone appears to overlie the [illegible]-bearing limestone in some places. In some

of the mines, the galena is concentrated to a greater or less extent in certain strata, while in other deposits there appears to be no regularity in the concentration of the ore. As a rule there are no well defined limits to the ore body, but the mineral contents of the rock gradually decrease until it is unprofitable to work. Only traces of zinc have been found in these mines, but iron and copper pyrites are found in limited quantities and these contain small amounts of nickel and cobalt, which have hitherto been saved. Many small crevices are noticed in these mines, but they die out in depth and could consequently have played no part as carriers of ascending solutions. Some faulting was noticed in one of the mines of this district. Though the ore deposits are frequently in proximity to such lines of disturbance, but little ore is found on the plane of the main fault and the others were of small throw and apparently of slight significance.

The crevice deposits of this and of the central district are totally different in appearance from these massive deposits. They are often horizontal and consist of a network of small channels opening into larger or chimney-shaped bodies. The ore occurs usually in a gangue of clay or barite. Some of these deposits are of the vertical or vein type and show unmistakable evidences of faulting. These are quite narrow and are filled with barite and clay in which the galena occurs. The Virginia mine in Franklin county was followed to a depth of 480 feet, but the crevice was only 4 to 6 inches in width.

There is one other variety of deposits, found in the central district and known as the circle type. In this the ore body is of a rudely conical shape, barren limestone being found on the exterior walls, and, in the interior, a circular mass of barren or nearly barren limestone debris. The galena is found in the breccia filling the circular space, attached to the limestone and associated with barite and calcite.

In attempting to account for the origin of these deposits the first question to be disposed of is that of the formation of the cavities in which the minerals are found. These cavities are of two kinds: 1) vertical or transverse to the strata; 2) horizontal or between the strata.

The various movements of the earth have, as already intimated, given rise to flexures and faults, generally small in

size. Crevices have also been opened by the contraction of the sediments. These crevices and fault planes acted as channels for meteoric waters, and were enlarged by them. The period succeeding the deposition of the Ozark rocks was one of great erosion. This is indicated by the small representation of the Upper Silurian and Devonian rocks, the country not being submerged during the greater portion of the time these rocks were being deposited elsewhere. The presence of organic acids in the meteoric waters would increase their solvent action. There was, moreover, much erosion after the deposition of the Lower Carboniferous rocks, and also after the deposition of those of the Coal Measures. That there was a slight deposit of these latter rocks over a large portion of southern Missouri, is probable. The area was above water, however, from an early date, in the Coal Measure period, with a possible slight exception, to the present day. The cavities of the large southwestern deposits were formed by this solvent action of surface waters which enlarged joint planes and crevices. Their location on the margin of the Coal Measures afforded opportunity for the access of waters carrying large quantities of organic acids, derived from decaying vegetation, which increased their solvent power materially. Added to this, the structure of the rocks of the Lower Carboniferous, pure limestone with many intercalated chert beds, furnished material readily dissolved, as well as contact planes affording easy access to the material. It may be readily conceived that once the limestone supporting these beds of chert dissolved, that chert, on account of its extreme brittleness, would fracture and break into the materials which now forms the breccia that characterizes these deposits.

Horizontal cavities, flat tabular-shaped spaces enlarging into chambers at times, such as are frequently met with in the southeast, had their origin in the same solvent action of water, here localized among certain stratification and joint planes where the rock yielded more readily to that action.

Those cavities, the filling of which have given us the type known as "circle deposits," are best explained by referring to certain caves which have their opening in the roof. One of these caves in Stone county was examined and surveyed by Dr. E. O. Hovey and the writer. The main feature was a

large, circular dome-shaped cavity with a small opening in the roof. In the center of this amphitheatre was a huge pile of debris which had loosened and fallen from the roof and sides. The cave had been formed by the solvent action of water and at this point had widened out, producing a large cavity, the interior of which was filled as described, by fragments of the roof and walls which had become detached and fallen in. The filling of the annular space thus left by limestone debris and the deposition of barite, calcite and galena in the interstices would give just such a circle deposit as seen at the Conlogue mine in Miller county, or the High Point in Morgan county.

The disseminated deposits of the southeast are formed by a metasomatic interchange of minerals, no cavity existing prior to their deposit.

The filling of the cavities is the next step. The gangue, as already stated, consists largely of country rock and of decomposition products derived therefrom. It may be readily conceived that fragments of rock, perhaps less soluble than the rest, becoming detached, would lodge in and assist in the filling of the cavities. The clays and sands were undoubtedly the product of the immense surface erosion then in progress, and were transported. Some of the clays—such as the tallow clay—were probably deposited chemically. The minerals were undoubtedly deposited from solution sometimes by chemical interchange, and sometimes by evaporation and concentration of solutions. It now remains to consider the source of the mineral solutions.

Many theories have been propounded regarding the source of the minerals forming ore bodies. So far as these refer to the subject under discussion, they may be expressed in three comprehensive hypotheses: 1. That the minerals were originally deposited in a concentrated condition. 2. That the minerals were derived from great depths. 3. That the minerals were widely diffused, but were gathered together and deposited by lateral secretion. The first of these theories insists that the minerals existed in the original oceanic waters in a considerable degree of concentration, and were deposited directly, or, in the case of disseminated deposits, by metasomatic action. It is hard for us to conceive, however, how such circumstances could have obtained. Besides the fact that in

waters carrying so high a proportion of mineral matter, animal and vegetable life could not have existed, this theory does not explain why such deposits are not found over a more widely extended area, especially when there appears to be but little difference in the rocks of adjoining areas. Moreover, it would be necessary to extend these metalliferous ocean waters to cover both the Lower Silurian and the Lower Carboniferous epochs. Further, while disseminated deposits might possibly be explained by such an hypothesis, the large deposits of the southwest are not.

The second theory is that the minerals came in solution from great depths. That this is true of many deposits of known true fissures is undoubtedly a fact, but in the present instance there are many obstacles in the way of this hypothesis. First, the crevices which have been found decrease in size as they descend. Some of them in immediate contact with ore bodies are entirely barren or carry but little ore. Again, underlying considerable portions of the ore-bearing rock is a large bed of sandstone, open, porous and water-bearing. No ore has been found in this rock, and it seems very strange that concentrated solutions could have passed through it and left no trace. In all well authenticated vein deposits where solutions have presumably come from great depths, lead ores carry a recognizable amount of silver, and accessory minerals, such as rhodochrosite, rhodonite, arsenical, antimonial and bismutiferous minerals are found. In Missouri, however, the lead carries from a trace to three or four ounces of silver per ton, with the exception of that from one acknowledged true fissure deposit in the granite at Einstein mine, where the ore carried considerable silver and where some of these accessory minerals were found.

The third hypothesis, that of the wide diffusion of the metals, supplemented by lateral secretion, has in it more local elements of evidence to support it than either of the others. The widespread existence of the metals in rocks has been demonstrated by Emmons, Sandberger, Forschammer, Bischof, and others. The action of lateral secretion has, however, been condemned by many writers who narrowed its application to the leaching of the immediately adjacent rocks. The question has thus been raised as to the sufficiency of the metalliferous

contents and as to whether the metals found in rocks were not introduced subsequently to the deposits of ore. In regard to the first point, it is not at all necessary to confine the area of supply to the immediately adjacent rocks: and in regard to the latter point, while it would be impossible to prove its falsity, it is in many cases highly probable that the minerals existed diffused in the rocks, from the fact that they are found in similar rocks in areas removed from ore deposits.

The applications of this theory, heretofore, however, appear to be inadequate to explain these deposits. Prof. Chamberlin's explanation of the Wisconsin deposits and, incidentally, of those of Missouri, introduced lateral secretion as a secondary cause, the primary one being concentration by oceanic currents in the Lower Silurian seas. This does not cover the case of the large Lower Carboniferous deposits of Missouri, and appears to be too theoretical to satisfy the demands of the case. Mr. F. C. Clerc suggests that the deposits were derived by lateral secretion from the Coal Measure shales. For this he requires a Quaternary submergence during which these shales were leached and their metalliferous burden deposited in the Lower Carboniferous rocks below. These Coal Measure shales, however, are very impervious to water and are not associated with all of the deposits, by any means. Moreover, no deposits of any importance are found in Coal Measure rocks, as would be expected.

The hypothesis here advanced to account for the origin of these metalliferous solutions is that of concentration through surface decomposition. This hypothesis starts with the proposition that the metals existed originally in the Archean crystalline rocks either diffused or in veins. On the degradation and decomposition of these rocks, the metalliferous minerals were partly transferred to the Silurian rocks and from these in a like manner transferred to the rocks of the Lower Carboniferous stage. Here the surface decomposition, extending through long periods, favored local concentration of the minerals in the meteoric waters and these, penetrating downward, deposited their load where conditions were favorable. The widespread occurrence of lead and zinc in nature is treated of in a comprehensive way in the report referred to.*

*Mo. Geol. Surv. Report on Lead and Zinc. Pt. 1. p. 30.

In support of this hypothesis a series of analyses of the rocks of the state was undertaken by the writer to determine the presence and amount of the metals in question. In the report referred to the results of these analyses are given in full, as well as the method pursued. Here it will be sufficient to give an outline of the results.

Metalliferous Contents of Missouri Rocks.

	Lead per cent.	Zinc per cent.
ARCHEAN ROCKS.		
Range of 8 analyses of 4 specimens	0.00197 to 0.00680	0.00139 to 0.01760
SILURIAN MAGNESIAN LIMESTONES.		
Range of 12 analyses of 6 specimens	Trace to 0.00156	Trace to 0.01538
LOWER CARBONIFEROUS LIMESTONES.		
Range of 15 analyses of 7 specimens	Trace to 0.00346	Trace to 0.00256

These analyses were made with great care and after much experimenting. While there are not a sufficient number of determinations to base many generalizations upon, they certainly afford results of a very significant nature. Copper, manganese, and barium sulphate were also determined, although the results of these determinations are not given here.

The presence of larger amounts of these metals in the impervious crystalline rocks certainly points to the conclusion that they existed there originally and were not introduced subsequently from more recent sources. The average contents of the limestones are thus 0.001009 % lead and 0.00239 % zinc, which is equivalent to 0.00198 lbs. galena and 0.00603 lbs. blende to the cubic foot of rock. This would give—

27.8 tons galena per square mile, 1 foot thick, or
13,900 tons galena per square mile, 500 feet thick, and
83.6 tons blende per square mile, 1 foot thick, or
41,500 tons blende per square mile, 500 feet thick.

Thus we find, according to our hypothesis, which does not limit the action of lateral secretion to the immediate wall rocks of the deposit, that the metalliferous contents of the rocks are ample to supply the ore deposits.

In support of this hypothesis we have evidence of great and prolonged erosion during different geological periods, as has been referred to before. This has occurred in Wisconsin as well and has been noticed by all the writers on the geology of that state. The hypothesis also accounts for the dolomization of the Lower Carboniferous limestones, the waters draining the Lower Silurian areas carrying in solution sufficient mag-

nesium bicarbonate to effect this. Besides this, the crevice deposits, which diminish in size as depth is reached, indicate that they were filled from above. Finally, the decay of large quantities of rock would give rise to correspondingly large bodies of ore, thus explaining the association of bulky deposits such as lead and zinc, with the comparatively soluble limestones.

Coming down to evidences of a more local nature we note that the large deposits of the southwest occur on the border of the Coal Measures. On examining the geological map of the state a tongue of Lower Carboniferous rocks will be noticed, extending to the eastward. This was probably the site of an estuary, through which large quantities of water derived from the central and eastern parts of the area flowed, containing the products of decomposition of the magnesian limestones of those sections. Thus was the material supplied. During the Coal Measure epoch an immense amount of decaying organic matter supplied the most perfect means for the reduction of the mineral in solution. The ample drainage constantly kept up the supply of metalliferous solutions and the deposition probably took place rapidly.

The crevice-shaped cavities were filled by similar solutions and were probably deposited in a similar manner by the aid of organic matter.

The disseminated deposits of the southeast are more difficult to explain. In general they are found in an open porous rock, which is probably one of the chief causes of their formations. In addition to this, the occurrence of more or less organic matter in the rock has had some influence, and the presence of shale beds has restricted and directed the flow of solutions. The crevices frequently found in these mines have been, in all likelihood, the avenues through which the solutions traveled in reaching the shallower of these deposits. This is evidenced by the frequent occurrence of galena in them. The deeper deposits of Flat River, however, cannot be readily referred to these crevices, on account of their narrowing and dying out in depth. There is, however, underlying these deposits a bed of sandstone, open, porous, and water-bearing, which might be suggested as a solution carrier. The water in this bed is under sufficient head to

cause it to rise well into the limestone rocks in the valley where the texture and structural conditions allow.

This statement includes the more important evidence which favors the hypothesis advanced. It is thought that it explains existing conditions better than does any other. Of course, there is much more additional work needed in the field and in the laboratory to supplement what has been done. There are many details of the chemistry of the processes of solution and deposition of these ores, the causes controlling the localization of deposits, etc., which need elucidation; and it is hoped that this report may be the means, to some extent, of stimulating such work.

ON THE MUD AND SAND DIKES OF THE WHITE RIVER MIOCENE.

By E. C. CASE, Ithaca, N. Y.

During the past few years attention has been called by various authors to the occurrence in widely separated localities of dikes of sandstone, which pierce for many feet the neighboring strata. The most pronounced occurrence of these dikes was reported by Mr. J. S .Diller from northern California (Bull. Geol. Soc. Am., vol I, p. 411). The article contains a full account of the nature and occurrence of these dikes and the author's conclusion that they are intrusions of sand from below, along cracks determined by volcanic action (p. 437). In describing the dikes he says, "the dikes are nearly vertical, wall-like masses of sandstone, varying from a mere film to 8 feet in thickness. * * * The dikes are parallel to the joints in the vicinity and so related to them as to indicate that the joints have not been produced by the dikes, but that on the contrary the position of the dikes has been determined by the joints."

From the occupancy of preëxisting joints by the dikes and from the position of the mica grains in microscopic sections of the sandstone Mr. Diller reaches the above stated conclusion, that the dikes are intrusions from below. To account for this intrusion he calls attention to the fact that below a certain level the materials of the earth's crust are saturated

with water, this water may be under hydrostatic pressure and certainly is under that of the overlying strata, so if any crack is opened from above to a saturated layer of loose sand the water will rush up and carry with it the sand. The subsequent hardening of this sand will produce the sandstone dikes. In evidence of the volcanic origin of the cracks occupied by the sandstone, the author of the paper calls attention to the parallelism of the dikes as illustrated in fig. 2, p. 413 of his article (op. cit.).

Later, an article appeared by Prof. Robt. Hay on the "Sandstone Dikes of Northwestern Nebraska" (Bull. Geol. Soc. Am., vol. III, p. 50). The dikes here described are similar to those described by Diller but are fewer in number, only two being noted. They are in the vicinity of Chadron, Nebraska, and pierce the clays of the so-called Pine Ridge. Prof. Hay regards them as intrusive from below, as will be seen from the following quotation from his article: "It (the main dike) does not on either side reach the top of the ravine, and a bluff of much greater elevation a few hundred feet away shows no sign of its presence, so it may be definitely regarded as having been formed before the completion of the soft clays and marls. * * One of the evidences of intrusive character lies in the structure of the laminated sheets on either side of the dike. In these the laminæ farthest from the dike are more argillaceous than inside and the inside laminæ are decidedly grooved, with vertical ridges, and grooves to correspond on the sides of the wall itself."

Prof. Hay does not attempt to explain the origin of these dikes but suggests that "these dikes may be related to the phenomena of mud volcanoes, as they were certainly intruded from below, and they may be expressive of the closing period of the Black Hills uplift." He also speaks of the existence of other dikes in the "bad lands" of South Dakota. It is the aim of this article to describe these dikes and show how they differ from those already described and possibly throw some light upon the formation of sandstone dikes in general.

The "bad land" or White River Miocene region of South Dakota is the seat of the eroded remnants of a vast lacustrine deposit of lower Miocene or Oligocene age. The entire thickness, according to Hatcher (Am. Nat., March 1893, p. 218), is

something over 600 feet. The beds are composed of alternating layers of a very fine-grained clay and sandstone, the latter passing at times into a hard conglomerate. The deposits were divided by Hatcher (loc. cit.) into two sets of beds, the Oreodon and the Titanotherium beds, named from their characteristic fossils. Later (Bull. Am. Mus. Nat. Hist., vol. v, p. 101) Wortman subdivided the upper into the Protoceras and Oreodon beds, so we have now:

The Protoceras beds, 180 feet, clays and coarse sandstones.
The Oreodon beds, 270 feet, mostly clays.
The Titanotherium beds, 175 feet, clays and sandstones.

It is in the two lower of these beds that the dikes occur. There are associated with the sandstones, veins of chalcedony, which may be either in connection with the sandstone or entirely separate, and the sandstone may exist entirely free from the crystals of quartz. Speaking of these veins, Hatcher says (Am. Nat., March, 1893): "In various portions of the Titanotherium beds there are numerous vertical veins of chalcedony running through the beds in every direction. These veins vary in thickness from that of a sheet of paper to about two inches. * * * Occasionally other minerals, as ordinary calcite and its common variety known as Iceland spar, are found in small cavities in these veins. * * * These veins occur only in certain localities of limited area. Any single locality is never more than a few miles in extent." These observations relate only to the lowest bed and to the veins of chalcedony. During the summer of 1894 the writer was able, while in the bad lands, to make some observation on the occurrence in both the lower beds of not only the chalcedony veins but also the mud or sandstone dikes not mentioned by Hatcher.

Let us consider first the dikes of soft sandstone or mud free from crystallized silica. The sandstone is not hard, but on the contrary is very soft and friable and seems in many cases to be little more than a mixture of sand and clay, sometimes passing into almost pure clay. They stand up from the surrounding clays but a few inches, in the greatest instance observed not to exceed six, and in weathering no blocks are formed, the disintegration is complete in the dike. The color of the intruded sandstone in the Oreodon beds is a light green

and it is easily recognized as identical with a layer of green sandstone lying near the base of the same beds, the Metamynodon sandstone of Wortman. In some cases it may be darker and softer from a larger mixture of clay, but never loses its distinctive sandy character. In the dikes of these beds and those below, the Titanotherium beds, one fact is especially noticeable, the contents of a dike at any point is universally from a stratum below.

The dikes commonly traverse the clays perpendicularly to their stratification and in a straight line, but with no common direction or any parallelism. They extend at least through the two lower beds, having here a vertical range of 450 feet. Different dikes were traced continuously for over a mile and were uniformly about three inches thick; other dikes reached an observed thickness of a foot, and I was informed by Dr. Wortman of some 18 to 20 inches wide. The thickness seemed to be constant in vertical range.

The strata on each side are undisturbed and only on the faces next the dike was there seen any evidence of motion. Here for perhaps a quarter of an inch in there was a mingling of the clays of different strata as if by water action, and a slight deflection upward. In some instances, at a point below the effect of surface wash, the sand had penetrated the clays for an inch or less on each side. There seems to be an entire lack of structure in the dikes such as is mentioned by Diller (Bull. Geol. Soc. Am., vol. I, p. 425) and Hay (Bull. Geol. Soc. Am., vol. III, p. 53).

In the cases where the dikes are connected with the chalcedony crystals the veins may exist on one or both sides of the intruded material between it and the clay walls of the crack. The absence of the crystals from one side or the other is not a local accident, but seems constant for large areas. In every case where it occurs, on one or both sides of the core, the crystals have a perfect vein structure, presenting a flat surface to the core or dike and one to the clay wall, and meeting irregularly in the middle. There are inclusions in the veins identical with the substance of the dike and also of calcite. One noticeable fact is that the veins of chalcedony in many observed cases, and probably in all, thin out from above downward.

Where the veins of chalcedony occur alone, they are so perfectly analogous in form and position with the dikes as to make it evident that the joints and cracks they occupy are of the same origin as those of the dikes, and they may throw added light on the method of the formation of these cracks. The veins run not only vertical and in all directions, as described by Hatcher, but have also an inclined position, crossing the nearly horizontal layers of clay at angles varying from 90° to 45°; no smaller angles were observed. From their hardness they resist weathering a great deal longer than the soft clays and stand up in jagged lines above the surface. When the clay around is removed and the support fails, pieces are broken off from the thin seams and fall on the neighboring clays; thus whole hills are covered with small sheets of quartz and are protected as by a shingle roof from the action of rain. Other local elevations are determined by the union of several veins in a common center, and from these centers run ridges, more or less pronounced, each determined by a vein and with a backbone of chalcedony. When a vein enters a hill obliquely to its stratification, it determines from its superior resistance to erosion the outer and upper edge of a cliff on the hillside.

When the veins meet and cross they do not penetrate and destroy each other, but fuse, and perfect homogeneous crosses were obtained from localities of such intersection. Frequent inclusions of clay and calcite are found in the veins, and the clay is uniformly from a layer below where it is found.

In seeking an explanation for these dikes it is evident we must seek for the cause of the cracks which they occupy, and in doing so we must consider the evidence furnished by the veins of chalcedony as well as the dikes proper. We find that the theory proposed by Diller to explain the dikes in California is here only partially applicable. The conclusion reached by him that the sand was forced up from below with water, receives conclusive confirmatory evidence from the dikes of the Miocene clays as shown above. On the other hand, the origin of the cracks receives no light from his explanation. The absolute lack of any parallelism in the cracks precludes the idea of their production by earth movements; nor were they produced by successive movements in different directions, as

is shown by the perfect fusion of the veins of chalcedony in crossing each other. They were formed all at the same time in cracks which crossed each other.

Hatcher (Am. Nat., March, 1893, pp., 208, 209) says of these veins: "On first thought the writer was inclined to attribute their origin to mud cracks, any particular region where they now occur having been for short periods, during seasons of low water, above the water level, and subjected to the action of the atmosphere and the heat of the sun became baked and cracked; just as we now so often see at low water along the mud flats of our streams and lakes. But it is obvious that if these veins owe their origin to mud cracks they would be filled, not with chalcedony, but with the same materials as the overlying beds; for when the waters again covered this region, the mud cracks would immediately be filled with the same materials that now compose the overlying beds." This objection to the mud cracks, it seems to me, will hardly hold, as it is evident, in many cases at least, that the cracks were immediately filled by the intrusion of upward moving sand and water.

Further, Hatcher says (loc. cit. p. 209): "It has since occurred to the writer that these cracks were not made while the particular strata in which they now appear occupied the immediate bottom of the lake, but after the overlying beds were deposited. The extreme fineness of the particles forming the clays of the Titanotherium beds in those places where these veins occur is evidence that the clays were deposited by a slow process of sedimentation in still waters. The bottom of a lake where such materials were being laid down would consist for several feet of a very thin mud or ooze. This would gradually become firmer toward the bottom as deposition continued, but would still mechanically retain a considerable per cent. of water. Later, when the entire overlying series of strata were deposited and the region brought permanently above the water level, this imprisoned water would gradually disappear by filtration or otherwise, aided perhaps by the pressure of the superincumbent beds. This loss of moisture in the clays would diminish their volume and bring about a readjustment of the particles composing them. The decrease in volume would be taken up in two ways: First, as

in the case of mud cracks, the particles would tend to collect about certain centers in the beds, and these centers of adhesion would increase laterally by the attraction of adjacent particles until cracks of varying thickness would form between the peripheries of adjacent centers of adhesion. The pressure of the overlying beds would determine the vertical direction of these cracks, and would afford the means for the second way, by which the decrease in the volume of the clays would be taken up, viz., by a decrease in the vertical thickness of the beds. These cracks thus formed far beneath the surface were afterwards filled by chalcedony dissolved out of the overlying beds by heated waters percolating through them." This explanation would account most perfectly for the veins which cut the strata of the clays in a line oblique to their planes of deposition and also the gathering of the veins together in common centers, causing the regions to resemble, as mentioned by Hatcher, huge septaria.

Conclusions: The dikes of mud and sand occupy pre-existent cracks which were filled by intrusions from below of water and suspended material. The water was forced into the cracks from porous layers either by hydrostatic pressure or that of the superincumbent strata, probably both combined. The cracks are not the results of earth movements. They are in all probability both mud cracks and cracks formed by segregation of the clays around local centers.

The veins of chalcedony were formed by the entrance into cracks of similar origin as those containing the dikes, of silicated waters. The cracks were already filled more or less completely with water and sand. The thinning out of the seams from above downward indicates that the silicated waters filtered in from above.

EDITORIAL COMMENT.

Secular Changes of Arctic Climate.

The astronomic theory of the causes of the Ice age, as advocated by Croll, Geikie, and Ball, is examined by Mr. E. P. Culverwell in the *Geological Magazine* for January and Feb-

ruary. Like Woeikof and others, he finds this theory insufficient to account for the climatic conditions of the Glacial period and the accumulation of its continental ice-sheets.

This conclusion, however, seems not to be inconsistent with the view presented in the last number of the AMERICAN GEOLOGIST (page 201), that the Kansan and Iowan stages of extended growth of the North American ice-sheet, with the intervening considerable retreat of the ice border in the upper part of the Mississippi basin, were due to the last two cycles in the precession of the equinoxes, bringing the winters of the northern hemisphere in aphelion. Dr. G. F. Becker's recent investigation of astronomic conditions favorable to glaciation lead him to conclude, altogether differently from the three British scientists first mentioned, that low eccentricity of the earth's orbit and high obliquity of the ecliptic are likely to promote snow and ice accumulation in high latitudes and mountain districts.* He thinks also that geographic conditions, as high land elevation and changes of marine currents, conduced toward the causation of the Glacial period. Granting that the Pleistocene ice-sheets were formed, as Dr. Becker indicates, by such concurrent geographic and astronomic conditions within the past 50,000 years, continuing until some 8,000 years ago, it seems to me highly probable that even the small present eccentricity (0.0168) was adequate to cause the interglacial recession of the ice-sheet in the interior portion of our continent between the Kansan and Iowan glacial stages, of which we have abundant evidence in buried forests, peat, and other fossiliferous beds enclosed between deposits of till in Ohio and the other states west and northwest to Minnesota. When we compare even this small ratio of eccentricity with the great range from the earth's mean surface temperature, produced entirely by the sun's heat, to the absolute zero, which Dewar finds to be —461° Fahrenheit† (this being the temperature, or rather the total absence of heat, in the interstellar spaces and upon the earth if its supply from the sun should cease), we may believe that so slight climatic effects as might result from the present eccentricity, in connection with equinoctial precession and nutation, could

*Am. Jour, Sci., III, vol XLVIII, pp. 95-113, Aug., 1894.

†McClure's Magazine, vol. III, pp. 557-562, Nov., 1894.

cause important fluctuations of the ice-sheets in both America and Europe.

Finding Croll's theory unsound, Mr. Culverwell advances one of his own, which is stated as follows:

Is it possible that there may have been any considerable interchanges of atmosphere between the earth and the regions of space through which it has passed? It is certain that there must have been some such interchange. Whether the atmospheric pressure is increasing or diminishing depends on whether, in the course of the earth's motion through space, more of the interstellar molecules get entangled in the earth's atmosphere than, leaving that atmosphere, get entangled in the interstellar gases through which the earth happens to be passing, and are thus dragged away from the earth. If once we were allowed to assume the magnitude of these changes, the whole difficulty of explaining Glacial or genial ages, so far as temperature changes are concerned, would vanish. For instance, if due to some gaseous conditions of space, or perhaps to the absorption into the atmosphere of the gaseous components of meteorites or shooting stars, there be an addition to the atmospheric pressure of one millimetre in three centuries, and if this process has been continued for 20,000 or 25,000 years, then it follows that some 25,000 years ago the atmospheric pressure would have been less by about one-tenth part than it is at present. This would be equivalent to raising land and sea by about 2,500 feet, for the blanketing effect of the decreased atmosphere would be about the same as that which now lies above a mountain 2,500 feet high. Thus a Glacial epoch might be produced *without any alteration in the geographical conditions.* And if, on the other hand, either through the earth plunging into a more gaseated region of space, or through some catastrophe, the atmospheric pressure were to be much increased, the resulting increase of temperature might be very great, and a genial age might be the result—a rise of 50°F. might readily be got........ If two bodies flying about in space come into collision they may generate a mass of gas, and if this mass of gas happens to get in the earth's path it may be caught up. Indeed, if we assume that the earth's atmosphere maintained a strict equilibrium with the interstellar molecules at, say, a distance of 1,000 miles from the earth's surface, then a doubling of the almost infinitesimal pressure there would necessitate a doubling of the pressure at the earth's surface. Of course this supposition is only used for the purpose of illustrating the fact that a small alteration of interstellar pressure, if spread over a sufficiently vast space, might eventually give rise to a considerable change in the atmosphere......the problem of atmospheric interchanges is so complicated that I may at all events hope to enjoy my hypothesis for a considerable time before anyone succeeds in giving it a really decisive overthrow. Its great advantage as a theory of the Glacial epoch is, that it does not require geographical changes such as are usually postulated in connection with all other theories, even the Astronomical one.*

*Geol. Magazine, IV, vol. II, pp. 64, 65, Feb., 1895.

Instead of regarding this hypothesis as possibly acceptable, the present writer sees an apparently crucial and insuperable objection to it in the great and sudden changes of climate which we know to have taken place in Arctic regions within the Pleistocene period. It has been generally held, and no doubt rightly, that the oncoming of the Glacial period was quite gradual and slow, and that its termination, with the melting away of the ice-sheets during the Champlain epoch, was geologically very sudden. This would perhaps accord with Culverwell's suggestion of slow loss of the earth's atmosphere while the ice-sheets were being amassed, and with sudden increase of the atmosphere bringing the Ice age to its end. Better, however, as I think, these wonderful climatic results can be shown to have depended on great epeirogenic uplifts of the land areas which became glaciated, and on the depression of these areas in the Champlain epoch, giving again a genial climate and melting away the ice. The observations which appear fatal to Culverwell's explanation, but not inconsistent with my epeirogenic theory, are those of Dall in Alaska and of Baron Toll in the New Siberia islands. After a stage of glaciation in each of these regions, there supervened a temperate climate, mostly melting away the ice-sheets; vegetation flourished on the drift which had been englacial and finally became superglacial; and herds of mammoths and other large animals pastured on the shrubs and herbage. Then *suddenly* came a much colder climate, after the culmination of the Ice age, under which the mammoths were overwhelmed and became extinct; but their frozen bodies, unthawed to the present day, are occasionally washed out of alluvial river banks. It is the *sudden change from mild conditions to those of severe cold* which the atmospheric theory cannot account for, and it may be confessed that we should not expect such a change to result even from any combination of epeirogenic movements, variations in volume and direction of sea currents, changes in prevailing courses of winds, exceptional storms, etc.; but the latter class of causes is undoubtedly the more probable, and the very deep fjords and continuations of river valleys beneath the sea tell unmistakably of great elevation of the glaciated lands immediately preceding the Ice age.

Without attempting to solve the puzzle, we may only add the reason for the assertion that the ice observed beneath the drift and mammoth remains by Dall, and by others before him, on the shore of Eschscholtz bay in Alaska,* and by Baron Toll on Lyakhoff island of the New Siberia group,† is due to the accumulation of névé snows and their consolidation into ice, rather than to the freezing of shallow lakes or infiltrating surface waters, as Russell, Dall, and Howorth have supposed. Russell's explanations may probably be true for many parts of the tundras of Alaska and Siberia; but in the two localities noted, where abundant animal remains occur in the drift above the ice, the structure of the ice itself proves it to be remnants of ancient ice-sheets.

The researches of Grad, Klocke, Forel, and others, have shown that all glacier ice preserves the granular structure which has its beginning in the change of the névé from snow to ice. Lake ice, on the other hand, has a prismatic or columnar structure. The glacier granules, varying in size and occasionally so large as from one to two or three inches in diameter, are irregular or without parallelism in the directions of their crystalline axes; but the prisms of lake ice are perpendicular to the freezing surface. Glacier ice in the process of melting reveals its granular condition, and this is distinctly noted by both Dall and Toll.

Writing of the ice-cliffs of Eschscholtz bay in northwestern Alaska, Dall remarks:

> The ice in general had a semi-stratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial. The outer inch or two of the ice seemed granular, like compacted hail, and was sometimes whitish.

On the New Siberia islands, about 1,400 miles west-northwest from the Alaskan ice-cliffs, the same structure is noted (*Nature*, Jan. 31, 1895):

> The chief geological result is the settling of the real positions of the layers which contain relics of the mammoth. They are undoubtedly Post-Glacial, as they overlie the masses of underground ice which form

*Am. Jour. Sci., III, vol. XXI, pp. 104-111, Feb., 1881; U. S. Geol. Survey, Bulletin 84, 1892, pp. 260-268. (Compare comments by N. H. Winchell, Am. Jour. Sci., III, vol. XXI, pp. 358-360, May, 1881.)

†Geol. Magazine, III, vol. X, pp. 107-111, March, 1893; Nature, vol. LI, p. 327, Jan. 31, 1895.

the chief rock of the great Lyakhoff Island, and which, as Baron Toll's observations now prove, are remains of the great ice-sheet which formerly covered both the islands and the mainland, and whose moraines have now been discovered on the mainland. Moreover, these ice masses have the typical granulated structure of the glacier ice, which proves that they have originated from the snow-cover, and could not have originated from any sort of running water. As to the Post-Glacial layers which overlie the above, they contain, besides shells of *Cyclas* and *Valvata* and well-preserved insects, full trees of *Alnus fruticosa*, willows, and birch, fifteen feet high, and bearing perfectly well-preserved leaves and cones. The northern limit of tree vegetation thus spread during the Mammoth period full three degrees of latitude higher than it spreads now, *i. e.*, up to the 74th degree, and the mammoths and rhinoceroses of the time lived upon the patches of meadow clothed with the above bushes. It is worthy of note, that the masses of underground ice are not found in the lower parts of the Arctic coast which are known to have been covered by the Post-Pliocene sea, and that they only occur where the land rises a few hundred feet above the present level of the sea—that is, above the level of the Post-Pliocene ocean. W. U.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Manual of Geology, treating of the principles of the science with special reference to American geological history. By JAMES D. DANA. 1087 pages; 1575 figures in the text; and two double-page maps. Fourth Edition. (American Book Co., 1895.) The first edition of this Manual was brought out in 1862, the second in 1874, and the third in 1880. After having been before the public a third of a century, and after its author has been engaged in geology and zoology during sixty years, the Manual in the present edition includes frequent illustrations and examples (as on pages 266, 280, etc.) of geological processes and principles from the author's observations during all these years, in which he has seen the science vastly expanded and the geologic exploration of North America and all other parts of the world carried forward until now few large districts remain entirely unknown as to the history recorded in their rock formations.

Professor Dana's studies of coral islands and of volcanoes during his voyage in the Wilkes Exploring Expedition, in 1838 to 1842, and in his visit to the Hawaiian islands again, in 1887, have given a special value to his discussion of these subjects; and his doctrine of the gradual growth of North America as a typical continent, first announced in 1846, has well stood the test of a half century of rapidly progressing investigation and theories. Throughout the volume, as in Lyell's works, a prominent and stimulating feature is the brief reference to discover-

ies and authors, with dates, marking stages of noteworthy extension of the science and establishment of its chief principles. For each of the great eras and periods, the authorship and date of first use of their present names, with their synonymy, are noted, affording useful clues for the student in entering any special studies of stratigraphy or paleontology.

The grand divisions of the volume, and the order of their consideration, are physiographic, structural, dynamical, and historical geology. In the preface Prof. Dana says: "As the rewritten book shows, new principles, new theories, and widely diverse opinions on various subjects are among the later contributions, along with a profusion of new facts relating to all departments of the science. The Cambrian formation has been traced through a large part of the continent, and the number of its fossils has been increased, chiefly by C. D. Walcott, from a few to hundreds. The Appalachian Mountain structure has been shown by Clarence King, Dr. G. M. Dawson, and R. G. McConnell, to have been repeated in the great post-Cretaceous mountain-making of the Rocky Mountain region. The Reptiles, Birds, and Mammals of the Mesozoic and Tertiary have continued coming from the rocks until the species recognized much outnumber those of any other continent. The cañons and other results of erosion in the west have thrown new light, through their investigators, on the work of the waters. Besides, the science of petrology has elucidated much of the obscure in the constitution, relations, and origin of rocks."

It was not to be expected that this summary of North American geology, by one who has held so prominent a part in its development, would accord with the views of other prominent geologists in all details, or even in some important correlations and opinions concerning the origin of debated formations. Taking two or three of the author's interpretations, where they differ from those held by others who have done much field work on the formations under consideration, we may note the reference of the Keweenawan series to the Middle or Lower Cambrian, instead of the Algonkian system, which latter is not accepted for its proposed place between the Cambrian and Archæan: the assignment of the Lafayette formation to the Pleistocene period, and to freshwater deposition by flooded rivers, instead of the Pliocene age and marine origin which have been much claimed for it; and the opinion that lake Agassiz, in the basin of the Red river of the North and of the great Manitoba lakes, was due to a land barrier on the north, as was thought by Gen. G. K. Warren, instead of to the retreating ice-sheet, as was suggested in 1872 by Prof. N. H. Winchell. This lake was the largest one of many due in common either to land or ice barriers. Professor Dana thinks that the fullness of the Champlain subsidence, at the end of the Glacial period, was attained after, not before, the time of lake Agassiz, and after the expanded Late Glacial representatives of the great lakes tributary to the St. Lawrence. Though the reviewer cannot agree with this opinion, it is most heartily welcomed as an impor-

tant contribution to the present active investigations by many workers in this field of our Quaternary lacustrine geology.

The whole volume is a rich thesaurus of the principles and methods of observation and reasoning, and includes also a vast multitude of the details, of this science in its varied branches treating of the formation and metamorphism of rocks, physiography, orogeny and epeirogeny, biologic evolution, and paleontology. It is not only a text-book for the college student, but a handbook for the professional geologist. It comes as the worthy consummation of a long life of exceptional earnestness and success in the work of teacher, investigator, editor, and author.

About a fifth part more pages, and a fourth more illustrations, are contained in this work than in its last previous edition. It is very well printed, and has a copious topical index, to which also one giving references to citation of authors might be usefully added. W. U.

Distribution of the Land and Fresh-water Mollusks of the West Indian region, and their evidence with regard to past changes of land and sea. By CHARLES TORREY SIMPSON. (Proc., U. S. National Museum, vol. XVII, pp. 423-450, with Plate XVI; 1894.) This essay treats of the Tertiary history of the West Indies, to which Profs. J. W. Spencer and R. T. Hill have recently given attention from the geologic side. The biologic conclusions of Mr. Simpson are as follow: "A considerable portion of the land snail fauna of the Greater Antilles seems to be ancient and to have developed on the islands where it is now found. There appears to be good evidence of a general elevation of the Greater Antillean region, probably some time during the Eocene, after most of the more important groups of snails had come into existence, at which time the larger islands were united, and there was land connection with Central America by way of Jamaica and probably across the Yucatan Channel, and there was then a considerable exchange of species between the two regions. At some time during this elevation there was probably a land-way from Cuba across the Bahama plateau to the Floridian area, over which certain groups of Antillean land mollusks crossed. At this time it is likely that the more northern isles of the Lesser Antilles, which seem to be volcanoes of later Tertiary and Post-Pliocene date, were not yet elevated above the sea, or if so they have probably been submerged since. After the period of elevation there followed one of general subsidence......The connection between the Antilles and the mainland was broken, and the Bahama region, if it had been previously elevated above the sea, was submerged; the subsidence continuing until only the summits of the mountains of the four Greater Antillean islands remained above the water. Then followed another period of elevation, which has lasted no doubt until the present time, and the large areas of limestone uncovered (of Miocene, Pliocene, and Post-Pliocene age) in the Greater Antilles have furnished an admirable field for the development of the groups of land snails that survived on the summits of the islands." W. U.

The Devonian System of eastern Pennsylvania and New York. By CHARLES S. PROSSER. (Bull. U. S. Geol. Surv., No. 120, pp. 1-81, 1894, distributed 1895.)

The author has given a very careful detailed study of the data derived from a large number of sections and bearing upon the correlation of the Devonian formations of Pennsylvania with those of New York. The accounts of the various sections abound in interesting details, and in the conclusions derived therefrom the author finds himself at variance in several particulars with the determinations of the Pennsylvania geologists. The latter regarded a dark sandy shale lying at the top of the Hamilton as the Genesee shale: Prosser shows that it has little resemblance lithologically and none in its fossils to the typical Genesee, which he holds to be absent in these sections. The geologists of the Pennsylvania survey referred to the Tully limestone a light gray stratum, rich in Hamilton fossils, especially its corals, but with none of the species characteristic of the Tully. As the upper beds of the Hamilton shales in central and western New York abound in limestones, and as these limestones in Monroe and Pike counties, Pa., are capped by a Hamilton shale, the inference is that they are not of the same age as strata referred to the Tully limestone in central Pennsylvania, whence typical Tully species have been reported. To the Lower Portage, Prof. Prosser refers 1,150 ft. of sandstone and shales regarded by I. C. White as Chemung. Overlying these is the Starucca sandstone, regarded by White as belonging to the upper Chemung and considered by Lesley as Catskill. Prosser considers it probable that "beginning with the greenish shales and sandstones of the Starucca and the New Milford red shales [considered by White as representing the base of the Catskill], there is a series of deposits equivalent to the Oneonta sandstone of New York, which, as is well known, gradually passes into the beds of typical Middle and Upper Portage in central New York."

The Delaware flags with *Orthonota ? parvula* Hall, and the Montrose shales with *Spirifer mesastrialis* in the upper part, are placed with the Chemung. J. M. C.

Notes Paléontologiques, II. Crustacés; Description de quelques Trilobites de l'ordoricien d'Ecalgrain. By J. BERGERON.

Under the name *Calymene lennieri*, the author describes an immense species of this genus equaling in size the great forms cited by Hall and Oehlert from the lower Devonian. A new species of *Trinucleus* (*T. grenieri*) is also described. J. M. C.

Ueber die stratigraphischen Beziehungen der böhmischen Stufen F, G, H, Barrande's zum rheinischen Devon. By E. KAYSER and E. HOLZAPFEL. (Jahrb. der k. k. geolog. Reichsanst., 1894, vol. 44, pp. 479-514.)

Since the full and final demolition by Kayser, of the alleged Silurian age of the F, G and H stages in the so-called "Silurian basin" of Bohemia, an accomplished fact which has received substantial corroboration from correlative faunas and careful students of the Devonian in various parts of the globe, there remained as "unfinished business" the determination of the precise equivalence and position of these faunas in the

Devonian column. Some variation of opinion has been expressed in regard to this by different paleontologists, none more conservative than that of Kayser, who has before regarded the three divisions, F (with the exception of F-1), G, H, as representing the lower Devonian, none more extreme than that of Frech, who suggested that they might be construed as an exemplification of the entire Devonian series. The present work is a detailed and exact analysis of the stratigraphical relations of these faunas with those of the Rhine section of the Devonian, and its essential results are as follows: The etage F-1 (including the "koniepruser-kalk") represents the entire lower Devonian and is equivalent to the Erbray limestone of France, some of the Ural limestones, and the Lower Helderberg of New York. The etage F-2 is not homogeneous, but consists of two sharply defined divisions; the higher, or Mnenian limestone, is the equivalent of the greifensteiner-kalk, and hence lower Middle-Devonian. Etage G-1 probably belongs to the same horizon. Etages G-2 and G-3, H-1 and H-2, are younger than earliest Middle-Devonian and are all later stages of the Middle-Devonian.

J. M. C.

Noch ein Wort über die Nothwendigkeit den Terminus "norisch" für die Hallstätter Kalke aufrecht zu erhalten. By A. BITTNER. (Verhandl. der k. k. geolog. Reichsanst. 1894, No. 15, pp. 391-398.)

There has been of late considerable discussion among the Austrian geologists as to the applicability of the term "norisch" or *norian*, by which Mojsisovics designated a certain zone of the Trias: and it has been contended, among other things, that the name was preëmpted by T. Sterry Hunt for a division of the Archean. Whether the term be written "norisch," norian, or noric, it is the same word, and Bittner shows that while Hunt introduced the term in 1870, Mojsisovics made use of the expression "norische Stufe" first in March, 1869. The term has, therefore, unquestionable priority in its application to the Trias.

J. M. C.

Thirteenth Annual Report of the New York State Geologist, 1894. 1,015 pp., 36 lithographic plates, 67 half-tone plates, 470 maps and cuts. This volume contains the report of D. D. Luther on the geological section at the Livonia salt shaft, with an introductory chapter by Prof. Hall and supplementary chapters by J. M. Clarke: also, special reports on the Helderberg limestones, the geology of Albany county, of Ulster county, and of the Mohawk valley, by N. H. Darton; on the economic geology of Albany and Ulster counties, by F. L. Nason: on the geology of Essex county, by J. F. Kemp; Clinton county, by H. P. Cushing; a part of St. Lawrence and Jefferson counties, by C. H. Smyth, Jr.; Cattaraugus and Chautauqua counties, by F. A. Randall; Chenango county, by J. M. Clarke: further, an account of the discovery of platycnemic man in New York, by W. H. Sherzer, the genera of the Fenestellidae, by G. B. Simpson, and the concluding part of the Handbook of the Brachiopoda, the first part of which was given in the report for 1891 (published 1894).

A new Insectivore from the White River Beds. By W. B. SCOTT. (Proc. Acad. Nat. Sci., Phila., 1894, pp. 446-48.) In this paper Dr. Scott describes a new insectivore resembling somewhat the genus *Sorex*, although differing sufficiently to remove it from this genus. It is called *Protosorex* and represents a very primitive type of *Soricidæ*. Description, as quoted from the author, as follows: Maxillary dentition much as in *Sorex*, but with less reduced third molar, and smaller internal cusps on last premolar. Mandible with four minute teeth between the molars and the large precumbent incisors." The species *P. crassus* (sp. nov.) is described from an adult individual and is "characterized by the short broad face, vaulted palate, straight alveolar border, and by the relatively large size." From the White River Miocene of South Dakota, and discovered by Mr. M. S. Farr. J. E.

Notes on a collection of Silurian fossils from Cape George, Antigonish, Nova Scotia, with descriptions of four new species. By HENRY M. AMI, D. Sc., F. G. S., etc. (Ex. Proc. Trans. Nova Scotia Inst. Sc., Halifax, N. S., 2d Series, No. 1, Part 4, pp. 411-415.) The paper is based on the collections of Silurian fossils made by Messrs. Hugh Fletcher and J. McDonald, during the summer of 1886, at the extremity of Cape George, Antigonish county, Nova Scotia. In age the fossils indicate the presence of Lower Helderberg or Ludlow rocks. They correspond to those of Division "D" of the Arisaig section in Pictou, although the facies is quite distinct so far as the collections go. The new species are not figured, but have been described with care.

The forms recognized from the collections comprise the following:

Annelida.

1. Serpulites longissimus *Murchison*, n. var.
2. Tentaculites niagarensis ? *Hall*.
3. " canadensis, n. sp.

Brachiopoda.

4. Discina nova scotica, n. sp.
5. Discina fletcheri, n. sp.
6. " orientalis, n. sp.
7. Lingula rectilatera *Hall*.
8. " sp. ?
9. Orthis (Rhipidomella) assimilis *Hall*.
10. Rhynchonella formosa *Hall*.

Lamellibranchiata.

11. Orthonota equilatera *Hall*.
12. Modiolopsis exilis *Billings*.
13. Nuculites (Clidophorus) erectus *Hall*.
14. " sp. indt.

Gasteropoda.

15. Bucania, sp.
16. Holopea reversa *Hall*.

Cephalopoda.

17. Orthoceras, cf. O. annulatum *Sowerby*.
18. " sp. indt.

Ostracoda.

19. Leperditia, sp.

Vertebrata.

20. Onchus (?) sp.

Geological map of Essex county, Massachusetts; Report on the Geology of Essex county, Mass., to accompany map. By JOHN H. SEARS, Curator of Mineralogy and Geology, Peabody Academy of Science, Salem. (Bull. Essex Institute, vol. XVI, 1894, pp. 22.) In this map and report the author presents the results of several years' work upon the complex rocks of northeastern Massachusetts. Several reports of progress have previously appeared in the same proceedings, beginning with those of 1889. The present report is mainly devoted to the systematic classification and description of the rocks represented on the map. Under plutonic rocks of hypidiomorphic granular structure are described (1) hornblendic-

granitite, (2) granophyric-granitite, contact-zone, (3) augite-nepheline-syenite, (4) hornblende-diorite. (5) quartz-augite-diorite, (6) muscovite-biotite-granite, (7) granitic-hypersthene-diabase (norite). Among effusive volcanic rocks of porphyritic structures, including tuffs, volcanic breccia and agglomerate, are (8) rhyolites or quartz-porphyry, under which head are united all the so-called felsites, etc. Of olivine rocks with no feldspathic constituent, Mr. Sears reports outcrops of (9) serpentine-peridotite in Newbury, (10) biotite-mica-peridotite in Andover.

Archæan rocks occur in the form of (11) hornblende-granitic-gneiss in Middleton, Boxford, and Georgetown, (12) porphyritic-granitic-gneiss in Georgetown, West Newbury, and Amesbury. As arkose or "conglomerate-granite" is noted (13) a muscovite-granitic-gneiss held by the author "to belong to a series of more or less crushed granite conglomerates which have been washed and reconsolidated from the decay of the muscovite-biotite-granite of the region or from some similar rock farther to the north." Of the schistose rocks is (14) ampibolite-gneiss of different origin in several parts of the field.

Members of the Lower Cambrian sediments occur as (15) mica-schist, (16) corderite-gneiss, (17) zoisite-gneiss, (18) limestone, slate, quartzite, and sandstone. (19) Another deposit is composed of large pebbles of granite, limestone, and mica-schist. (20) Bostonite or keratophyre covers a breccia and other members of the rhyolite and quartz-porphyries sloping into Marblehead harbor. Bostonite is a name given by Rosenbusch to a rock like keratophyre, which occurs as a dike instead of as a surface flow. (21) A tinguaite dike in Manchester, the sole recorded occurrence in Massachusetts, cuts the hornblende granitite and augite-nepheline-syenite at Pickard's point. (22) Essexite, a basic augite-nepheline rock of porphyritic habitus outcrops on Salem Neck, Winter island, and in Beverly and Marblehead. (23) Dikes of quartz-porphyry are shown on the map in the places where they cut more ancient rocks of the same series or the old rhyolites. (24) As arkose or conglomerate-granite is described a small deposit at Magnolia and in Saugus Centre. The map also shows (25) diallage-gabbro, rocks first noticed by Dr. M. E. Wadsworth; (26) a liparite dike about seven feet wide cutting diorite and granite, in Throckmorton's cove on the Marblehead side of Forest river: (27) red slate, the "jaspilite" of Saugus Centre, Lynn, and Nahant, a member of the Olenellus Cambrian; (28) andalusite-schist on Nahant, at Lynn, etc.; (29) vein rocks, carrying lead, silver, and copper ores.

A list of publications referring to the geology of Essex county closes this report. In the field work on which this map is based, Mr. Sears collected several thousand specimens, and over one thousand thin sections have been examined under the microscope. Material has also been collected for the preparation of a map of the glacial geology of the same area. To Mr. Sears is due great credit for the indefatigable industry with which he has worked out this intricate maze of highly altered sediments and entangled series of intrusive and effusive igneous rocks. As a field for petrographic study, this area promises to be unsurpassed by any upon the Atlantic coast. It is hoped that the

author will present another report giving more in detail the relations in time and structure of these igneous rocks, together with an analysis of the facts in so far as they may have a bearing upon the question of magmatic variations and the sequence of volcanic eruptions. J. B. W.

Evidence of Subsidence and Elevation in Essex county in recent geological time, as shown by field work at the sea shore. By JOHN H. SEARS. (Bull. Essex Institute, vol. XVI, 1894, pp. 13.) In this paper, Mr. Sears notes the occurrence of stumps of forest trees covered by six to thirteen feet of water at high tide at Nahant, by twelve or fourteen feet at low water on the Beverly shore, and instances of submerged peat and leaf accumulations, together with the wings of water beetles and fragments of other living species. From a comparison of soundings made by the author in the summer of 1894, with those made by Dr. Nathaniel Bowditch in 1804 and 1805, in Salem and Marblehead harbor, it appears that there is an increase in depth of water amounting to from 1½ to 2 feet. This conclusion is corroborated by recent work of the U. S. Hydrographic Bureau in the same waters. From the accepted rate of subsidence—two feet a century—Mr. Sears concludes that the submerged forests and peat beds were flourishing from 1,000 to 1,200 years ago.

Evidences of postglacial elevation are obscure in this part of the country. Absence of drift and presence of waterworn ledges at elevations from 50 to 150 feet above sea level are taken as evidence of old shore lines: but in another passage the author argues against the absence of drift at these higher levels as proof of its removal by waves. Between 25 and 100 feet above the present sea level are areas of sand similar to existing beaches, but they have afforded no remains of a marine fauna. Two photographic reproductions showing submerged stumps and logs, at Pond beach, Nahant, and submerged peat with forest trees at Mingo's beach, Beverly, accompany the report. J. B. W.

Geological Survey of Alabama. Report on the Geology of the Coastal Plain of Alabama. By EUGENE ALLEN SMITH. State Geologist. Octavo, pp. 759, 29 plates of views and sections. Montgomery, 1894. This volume pertains to the southwestern three-fifths of the state, known as the agricultural region. The rocks are Mesozoic and Neozoic, loosely consolidated, gently dipping, in general, seaward, rarely with elevations over 500 feet. In addition to a description of the geology proper two other parts are added, one on the phosphates and marls, and one giving special descriptions of the counties of the Coastal plain. The author has been assisted by K. M. Cunningham on the Diatomaceæ of the Pleistocene and other microzoa: L. C. Johnson, on the Lafayette formation: T. H. Aldrich on the paleontology of the Clayton: and Daniel W. Langdon on the Tertiary and Cretaceous formations east of the Alabama river. By far the greater portion of the volume is by the state geologist. A large part of the volume is made up of descriptive details, though arranged systematically, and evinces laborious field work and careful consideration of published literature. It is one of the most voluminous, as it is one of the most important, of the publications of the present Alabama survey. N. H. W.

Missouri Geological Survey, Vol. V. *Paleontology of Missouri.* (Part II). By CHARLES ROLLIN KEYES, State Geologist. Pp. 266, with 32 plates. Jefferson City, 1894. This volume, which continues the plan begun by part I, treats of the polyzoans, brachiopods, lamellibranchs, gasteropods, cephalopods, and vertebrates. The two volumes constitute a useful catalogue by means of which with the aid of the plates, which are excellent, most of the fossils of the state can be referred to their stratigraphic and geographic places. The future investigator will find this compend a necessary *vade mecum* for guidance to the principal literature. The work does not aim to be anything more than a synopsis of the present knowledge of the paleontology of the state. It remains yet for the Missouri survey to enter upon the real investigation of the paleontology of the state. This gathering together and classification of what is known already is the necessary first step to such an investigation, and has a wide usefulness, *per se*, should the work go no further for many years.

N. H. W.

Beiträge zur Kenntniss der Gattung Oxyrhina. By CHARLES R. EASTMAN. (Paleontographica, XVI Band, pp. 149-192. Taf. XVI-XVIII.) This excellent monograph is in direct line with the tendencies of the better class of recent paleontological work, which on the geological side deals with faunas as an aid to detailed stratigraphy, and on the biologic side lays particular stress upon the careful revision of work already done, thereby aiding morphological inquiry, and enabling the phylogenetic history of living zoological groups to be made out with greater accuracy. Minute study of ancient organisms from this standpoint leads to a philosophic insight and to a keen discrimination of morphological features which are entirely lost sight of when the description of a new species is made the chief result of a consideration of fossil forms.

Oxyrhina comprises a widely known group of sharks, the triangular teeth of which are probably more familiar to the popular mind than any other fossils. After a historical introduction and a very full list of the older allusions to the fossils, there is given a full account of the characters and occurrence of the principal form, *O. mantelli* of Agassiz. The systematic consideration of the various species which are now regarded as belonging to the genus is especially helpful and shows a number of important changes in nomenclature. A list of synonyms and their proper references follows; also a table of the geological distribution of the known species. The three plates accompanying the memoir illustrate lucidly the different anatomical characters of the forms. Paleontologists are under great obligations to Dr. Eastman for working out so carefully this long neglected group. It is understood that the author is now at work in the Museum of Comparative Zoology at Cambridge on other groups of fishes.

C. R. K.

RECENT PUBLICATIONS.

I. Government and State Reports.

Third Ann. Rept. of the Bureau of Mines, Ontario. 205 pp. Toronto. 1894.

Geol. Sur. of Ohio, vol. VII, pp. xvi, 700 (with 56 plates, a geological map of the state, and 10 maps showing outcrop boundaries of principal coal seams), contains: Geological scale and geological structure of Ohio, Edward Orton; The clays of Ohio, their origin, composition, and varieties, Edward Orton, jr.: The coal fields of Ohio, Edward Orton: Contributions to the paleontology of Ohio, R. P. Whitfield; Observations on the so-called Waverly group of Ohio, C. L. Herrick: Fossils of the Clinton group in Ohio and Indiana, A. F. Foerste: The fossil fishes of Ohio, E. W. Claypole and A. A. Wright: New and little known Lamellibranciata from the Lower Silurian rocks of Ohio and adjacent states, E. O. Ulrich.

South Dakota Geol. Sur., Bull. No. 1. A preliminary report on the geology of South Dakota, by J. E. Todd, state geologist. vii and 172 pp., 5 plates, and a geological map of the state, 1895.

Missouri Geol. Sur. Third biennial report of the state geologist, C. R. Keyes. 60 pp., 1895.

U. S. Geol. Sur., Bull. 120. The Devonian systems of eastern Pennsylvania and New York, C. S. Prosser. 81 pp., 2 plates, 1894.

Geol. and Nat. Hist. Sur. of Minn., 23d (1894) Ann. Rept., contains: The origin of the Archean greenstones, N. H. Winchell: Preliminary report on the Rainy Lake gold region, H. V. Winchell and U. S. Grant: The topographical survey of Minnesota, W. R. Hoag; Historical sketch of the discovery of mineral deposits in the lake Superior region, H. V. Winchell: Late Glacial or Champlain subsidence and re-elevation of the St. Lawrence river basin, Warren Upham; Notes on Minnesota minerals, C. P. Berkey: Chemical analyses: The progress of mining, N. H. Winchell: Compressive strength of some Minnesota bricks and building stones: Notes upon the bedded and banded structures of the gabbro and upon an area of troctolyte, A. H. Elftman.

Geol. Sur. of Alabama. Report on the geology of the Coastal plain of Alabama, by E. A. Smith, L. C. Johnson and D. W. Langdon, Jr.: with contributions to its paleontology, by T. H. Aldrich and K. M. Cunningham. Pp. i-xxiv, 1 759, pls. 1-29, 1894.

Missouri Geol. Sur. vols. 4 and 5: Paleontology of Missouri, by C. R. Keyes. Pt. I, pp. 1-271, pls. 1-32: pt. II, pp. 1-266, pls. 33-56: 1894.

Missouri Geol. Sur. vols. 6 and 7: Lead and zinc deposits, by Arthur Winslow, assisted by J. D. Robertson. In two sections: pp. 1-21, 1-763, 1894.

Cal. State Mining Bureau. 12th Ann. Rept. State Mineralogist, J. J. Crawford: pp. 1-541, 1894.

II. Proceedings of Scientific Societies.

Jour. Elisha Mitchell Sci. Soc., vol. XI, part 1 1894, contains: The exhaustion of the coal supply, F. P. Venable: Sulphur from pyrite in Nature's laboratory, Collier Cobb.

Bull. Nat. Hist. Soc. New Brunswick, No. 12, 1894, contains: The crystalline rocks near St. John, N. B., W. D. Matthew: Post-glacial faults at St. John, N. B., G. F. Matthew: Outlets of the St. John river, G. F. Matthew: Some evidences of a glacial epoch, C. R. Fischer: The mountain systems of America, L. W. Bailey.

Proc. Acad. Nat. Sci. Phila., 1894, pt. 3, contains: The Sadsbury steatite, T. D. Rand.

Proc. Amer. Acad. Arts and Sci., whole ser. vol. 29, 1894, contains: Further observations upon the occurrence of diamonds in meteorites, O. W. Huntington: The Smithville meteoric iron, O. W. Huntington.

Jour. of the Cincinnati Soc. Nat. Hist., vol. 17, No. 2, July, 1894, contains: The granites of Cecil county in northeastern Maryland, Part II, G. P. Grimsley: The St. Peter's sandstone, J. F. James.

The same, vol. 17, No. 3, Oct., 1894, contains: Description of some Cincinnati fossils, S. A. Miller and C. L. Faber.

Bull. Geol. Soc. Amer., vol. 6, pp. 1-28, Nov. 1894: Proceedings of the sixth summer meeting, held at Brooklyn, New York, August 14 and 15, 1894, H. L. Fairchild, Sec'y.

The same, pp. 29-54, Nov. 1894; Kansas River section of the Permo-Carboniferous and Permian rocks of Kansas, C. S. Prosser.

The same, pp. 55-70, Dec., 1894: The extension of uniformitarianism to deformation, W J McGee.

The same, pp. 71-102, Dec., 1894: Review of our knowledge of the geology of the California Coast ranges, H. W. Fairbanks.

The same, pp. 103-140, Jan., 1895: Reconstruction of the Antillean continent, J. W. Spencer.

The same, pp. 141-166, Jan., 1895. Evidences as to change of sea-level, N. S. Shaler.

The same, pp. 167-198, pl. 2, Jan. 1895. The Magnesian series of the northwestern states, C. W. Hall and F. W. Sardeson.

III. Papers in Scientific Journals.

Jour. of Geol. Oct.-Nov., 1894, contains: Glacial studies in Greenland, T. C. Chamberlin; On a basic rock derived from granite, C. H. Smyth, Jr.: The quartzite tongue at Republic, Michigan, H. L. Smyth: A sketch of geological investigation in Minnesota, N. H. Winchell; Studies for students—The drift, its characteristics and relationships, R. D. Salisbury.

The same, Nov.-Dec., 1894, contains: George Huntington Williams, J. P. Iddings: Glacial studies in Greenland, II, T. C. Chamberlin: A petrographical sketch of Ægina and Methana, H. S. Washington: The basic massive rocks of the lake Superior region, W. S. Bayley; The geological surveys of Arkansas, J. C. Branner; The drift, its characteristics and relationships, R. D. Salisbury.

Amer. Naturalist, Dec., 1894, contains: Quaternary time divisible in three periods, the Lafayette, Glacial and Recent, Warren Upham.

Amer. Jour. Sci., Dec., 1894, contains: Duration of Niagara falls, J. W. Spencer: Distribution and probable age of the fossil shells in the drumlins of the Boston basin, W. O. Crosby and H. O. Ballard; Post-glacial faults at St. John, N. B., G. F. Matthew.

The same, Jan., 1895, contains: Late Glacial or Champlain subsidence and reëlevation of the St. Lawrence river basin, Warren Upham: Preliminary notice of the Plymouth meteorite, H. A. Ward.

School of Mines Quarterly, Nov., 1894, contains: A treatise on ozokerite, E. B. Gosling; Carborundum: its history, physical properties and chemistry, J. A. Mathews.

Bull. Amer. Geog. Soc., Dec. 31, 1894, contains: The Cape York ironstone, R. E. Peary.

Johns Hopkins Univ. Circulars, vol. XIV, Jan., 1895, contains: The origin of the oldest fossils and the discovery of the bottom of the ocean, W. K. Brooks.

Amer. Jour. Sci., Feb., 1895, contains: Relation of gravity to continental elevation, T. C. Mendenhall; Observations upon the glacial phenomena of Newfoundland, Labrador, and southern Greenland, G. F. Wright: Recurrence of Devonian fossils in strata of Carboniferous age, H. S. Williams; Constituents of the Cañon Diablo meteorite, G. A. Derby: The inner gorge terraces of the upper Ohio and Beaver rivers, R. R. Hice: The glacial land-forms of the margin of the Alps, H. R. Mill; Lower Cambrian rocks in eastern California, C. D. Walcott; Pithecanthropus erectus, Dubois, from Java, O. C. Marsh.

Popular Science Monthly, Feb., 1895, contains: The United States Geological Survey, C. D. Walcott.

Journal of Geology, Jan.-Feb., 1895, contains: The basic massive rocks of the lake Superior region, IV, W. S. Bayley; A petrographical sketch of Ægina and Methana, II, H. S. Washington; Lake basins created by wind erosion, G. K. Gilbert; On Clinton conglomerates and wave marks in Ohio and Kentucky, A. F. Foerste; Glacial studies in Greenland, III, T. C. Chamberlin; Agencies which transport materials on the earth's surface, R. D. Salisbury.

Science, Jan. 18, 1895, contains: The Baltimore meeting of the Geological Society of America, J. F. Kemp: The Connecticut Sandstone group, C. H. Hitchcock.

Science, Feb. 15, 1895, contains: Current notes on physiography, W. M. Davis.

Amer. Jour. Sci., March, 1895, contains: The Appalachian type of folding in the White Mountain range of Inyo Co., Cal.; C. D. Walcott: Notes on the southern ice limit in eastern Pennsylvania, E. H. Williams; The succession of fossil faunas at Springfield, Mo., S. Weller; Drift bowlders between the Mohawk and Susquehanna rivers, A. P. Brigham.

Amer. Naturalist, March, 1895, contains: In the region of the new fossil: Dæmonelix, F. C. Kenyon; Minor time divisions of the Ice age, Warren Upham.

IV. Excerpts and Individual Publications.

The geology of Denver and vicinity, C. L. Cannon, Jr. Proc. Colorado Sci. Soc., 36 pp.

A suspected new mineral from Cripple creek, F. C. Knight. Proc. Colorado Sci. Soc., 6 pp.

Phylogeny of an acquired characteristic, Alpheus Hyatt. Proc. Am. Philos. Soc., vol. 32, pp. 349-647, 14 pls.

Additional notes on the new fossil, Daimonelix. Its mode of occur-

rence, its gross and minute structure, E. H. Barbour. Univ. Studies, Nebraska, vol. 2, pp. 1-16, pls. 1-12, July, 1894.

Some Coal Measure sections near Peytona, West Virginia, B. S. Lyman. Proc. Am. Philos. Soc., vol. 33, pp. 282-309, 2 maps, Nov., 1894.

Cone-in-cone: how it occurs in the Devonian series in Pennsylvania, U. S. A., with further details of its structure, varieties, etc., W. S. Gresley. Quar. Jour. Geol. Soc., vol. 50, pp. 731-739, 2 pls., 1894.

The evolution of the ungulate mammals, H. L. Fairchild. Proc. Rochester Acad. Sci., vol. 2, pp. 206-209, June, 1894.

The geological history of Rochester, N. Y., H. L. Fairchild. Do., pp. 215-223.

The length of geologic time, H. L. Fairchild. Do., pp. 263-266.

The Ore Deposits of the United States. By J. F. Kemp. 2d edition; pp. i-xviii, 1-343, 94 illustrations: The Scientific Publishing Co., New York and London, 1895.

Revision of the bivalve mollusks of the coal-formation of Nova Scotia, J. W. Dawson. Canadian Rec. of Sci., Oct., 1894; 18 pp.

Lead and zinc deposits of Missouri, Arthur Winslow. Trans. Amer. Inst. Mining Eng., Bridgeport meeting, Oct., 1894; 56 pp., 4 pls.

The origin of the Archean greenstones, N. H. Winchell. Geol. and Nat. Hist. Sur. Minn., 23d Ann. Rept., pp. 4-35, Jan., 1895.

Observations upon some structural variations in certain Canadian Coniferæ, D. P. Penhallow. Trans. Roy. Soc. Canada, sec. 3, 1894, pp. 19-41, pls. 1-4.

George Huntington Williams: The minutes of a commemorative meeting held in the Johns Hopkins University, Oct. 14, 1894. Pp. 1-19; Baltimore, 1894.

On new forms of marine Algæ from the Trenton limestone, with observations on Buthograptus laxus Hall, R. P. Whitfield. Bull. Amer. Mus. Nat. Hist., vol. 6, pp. 351-358, Dec. 20, 1894.

Dislocations in certain portions of the Atlantic Coastal plain strata and their probable causes, Arthur Hollick. Trans. N. Y. Acad. Sci., vol. 14, pp. 8-20, Oct. 15, 1894.

The nickel mine at Lancaster Gap, Penn., and the pyrrhotite deposit at Anthony's Nose, on the Hudson, J. F. Kemp. Trans. Amer. Inst. Mining Eng., Bridgeport meeting, Oct., 1894: pp. 14.

The Cretaceous Foraminifera of New Jersey, part II, Original investigations and remarks, Anthony Woodward, Jour. of the New York Micro. Soc., 1894, pp. 91-141.

A summary of progress in mineralogy and petrography in 1894. Petrography and mineralogy by W. S. Bailey: Mineralogy by W. H. Hobbs. From monthly notes in the American Naturalist.

Notes on a collection of Silurian fossils from Cape George, Antigonish Co., N. S., with descriptions of four new species, H. M. Ami. Proc. and Trans. N, S. Acad. Sci., 2d Ser., vol. I, pp. 411-415.

Notes on the geology of the western slope of the Sangre de Cristo range in Costillo Co., Colo., E. C. and P. H. van Diest. Proc. Colo. Sci. Soc.: 5 pp. and map: read Nov. 5, 1894.

PERSONAL AND SCIENTIFIC NEWS.

The Lake Superior Mining Institute held its third annual meeting March 6th to 8th. The members met at Duluth on the moring of the 6th and were conveyed by a special train, which was at the disposal of the institute for three days, to the Mesabi iron range. The Mountain Iron and the Mesabi Mountain (Oliver) mines were examined. These two mines are worked by the "open pit" method and are the largest shippers on the range, each having produced over half a million tons of iron ore during 1894. The Auburn mine, where the "milling" process is used, was also visited the same day. An evening meeting was held at Virginia. The next morning the party examined the Canton and Biwabik mines, and then went to the Vermilion iron range where the well known mines of the Minnesota Iron Co. at Soudan were inspected. In the evening an interesting meeting was held at Tower. The next day the mines at Ely, also on the Vermilion range, were examined, and the party returned to Duluth that afternoon.

The success of the excursion, in which about seventy persons participated, was due largely to the efforts of the secretary, Mr. F. W. Denton. Mr. H. V. Winchell prepared a guide book of the ranges, which was of great service to the excursionists. Among the papers presented at the evening meetings were the following:

The relations of the vein at the Central mine, Keweenaw county, Mich., to the Kearsarge conglomerate. By Dr. L. L. Hubbard, State Geologist of Michigan.

The geology of the eastern end of the Mesabi iron range in Minnesota. By Dr. U. S. Grant.

Open pit mining with special reference to the Mesabi deposits. By Mr. F. W. Denton.

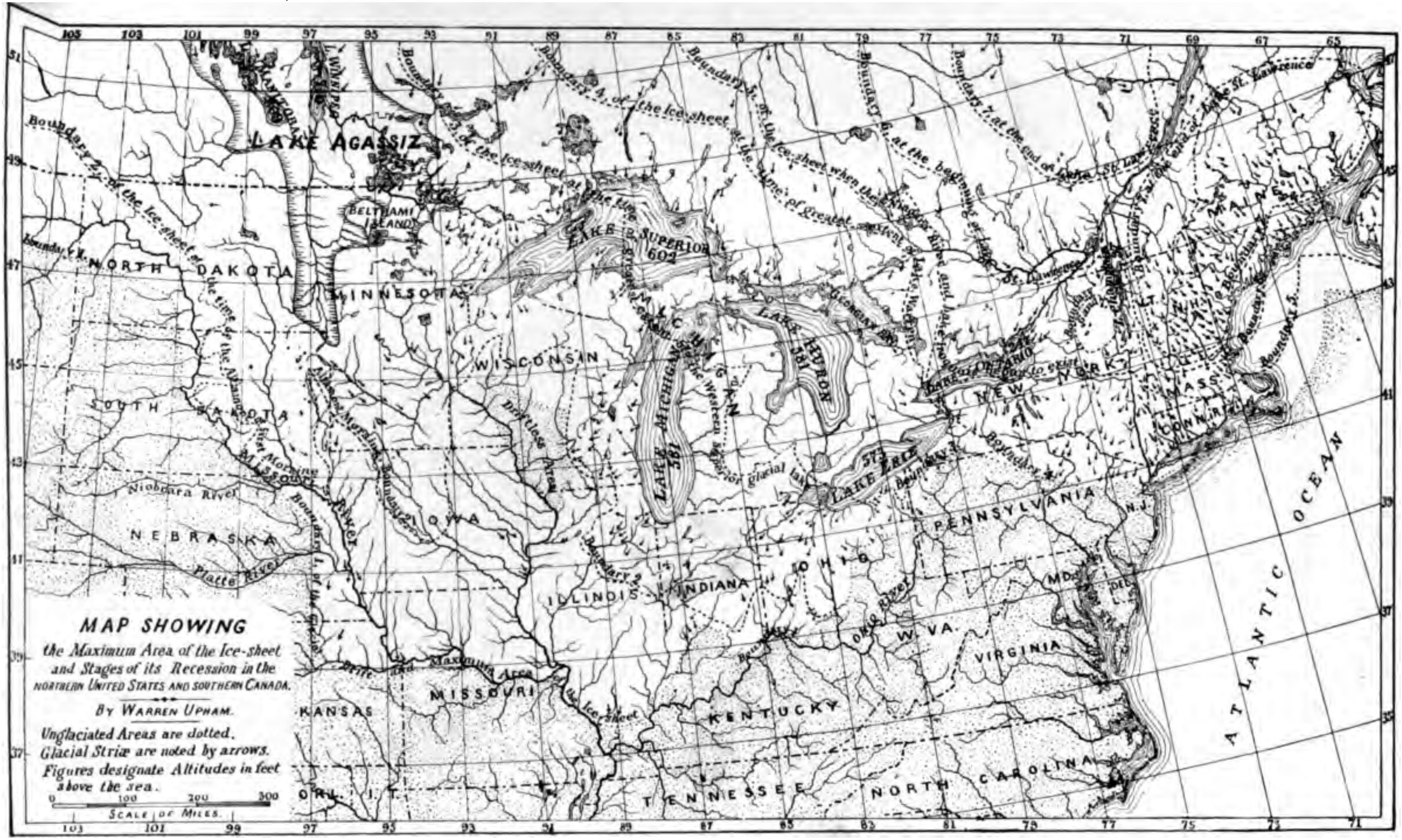
A uniform method of sampling and analysis of iron ores. By Mr. F. F. Sharpless.

The distribution of phosphorus and the system of sampling at the Pewabic mine, Iron Mountain, Mich. By Mr. E. F. Brown.

The Legislature of Michigan is considering the advisability of entering upon a complete topographical survey of the state in coöperation with the U. S. Geological Survey.

In Maine efforts are being made looking towards the establishment of a geological survey.

Mastodon bones, representing at least three individuals, with a molar and vertebra of *Equus fraternus* Leidy, were found in June, 1894, in Hyde Park, near the Cincinnati city boundary, at a hight of 240 feet above the Ohio river (low water), or 670 feet above the sea. The bones were 5 to 13 feet below the surface, in stratified clay, closely associated with till. Prof. Edward Orton considers the bone-bearing deposit postglacial. (Journal of Cin. Soc. Nat. Hist., vol. XVII, pp. 217-226, with a map and two plates, Jan., 1895.)



STAGES OF RECESSION OF THE NORTH AMERICAN ICE-SHEET.

(DIVISIONS OF THE TIME OF ICE DEPARTURE, IN ITS RELATION TO GLACIAL LAKES)

THE

AMERICAN GEOLOGIST.

VOL. XV. MAY, 1895. No. 5.

CLIMATIC CONDITIONS SHOWN BY NORTH AMERICAN INTERGLACIAL DEPOSITS.*

By WARREN UPHAM, Cleveland, Ohio.

(Plate X.)

CONTENTS.

FLUCTUATIONS OF THE BORDERS OF THE ICE-SHEET DURING BOTH ITS GROWTH AND DECLINE.

Within moderate limits the snow accumulation producing and maintaining the Pleistocene ice-sheet in North America is known to have fluctuated, now relinquishing and again reclaiming certain marginal tracts, as shown by fossiliferous beds intercalated between deposits of till. Both the time of general growth and the time of general decline of the ice-sheet were undoubtedly diversified by these oscillations. Stages of the recession, as indicated by the series of great glacial lakes on the northern borders of the United States, are shown in Plate X. Interglacial beds, enclosing fossils and

*Read before the Geological Society of America at the Baltimore meeting, Dec. 28, 1894.

layers of peat and lignite, are reported by Dr. G. M. Dawson, Dr. Robert Bell, and others of the Canadian Geological Survey, from the Pacific coast in British Columbia, the Saskatchewan plains, and the country bordering the southwest side of Hudson and James bays. On the north shore of lake Ontario, at Toronto and Scarboro, very interesting fossiliferous interglacial deposits are described by Hinde and Coleman. In the United States they are chiefly confined to the upper Mississippi basin, the principal phase of their development being the well known "forest beds" of the drift series in Ohio, Indiana, Illinois, Iowa, and southeastern Minnesota.

In these states an important oscillation of the ice-border took place after the formation of the early Kansan member of the Mississippi drift series.* From the Kansan stage of maximum area of the ice-sheet, it was melted back probably to the northern limits of the forest beds in the upper Mississippi region. During the ensuing Iowan stage of reädvancing glaciation, increased snowfall and ice accumulation, with inflow of ice bringing drift from the north, overspread these interglacial forests, which had grown up to the border of the previously retreating ice, if not indeed upon its drift-covered margin, as now on that of the Malaspina glacier or ice-sheet.

During all the glacial recession, interrupted after the beginning of the moraine-forming or Wisconsin stage, when the ice boundary (numbered 2 on plate X) was at the Altamont or first moraine, by many pauses and slight reädvances, which are marked by the knolly and hilly moraine belts, trees, shrubs, and herbaceous plants likewise probably grew close to the ice-front and may here and there have become covered by the late Wisconsin till and moraines, as during the more extended Iowan oscillation of the ice boundary. Mainly, however, the glacial fluctuations or pauses or slackening in the rate of retreat, whereby the moraines were amassed, appear not to have been sufficient for the envelopment of fossiliferous beds by overlying till or morainic drift. A most

*In two chapters (pages 724-775, with maps forming plates XIV and XV) of J. Geikie's "The Great Ice Age," third edition, 1894, Prof. T. C. Chamberlin proposes a chronologic classification of the North American drift under three formations, named in the order of their age, beginning with the earliest, the Kansan, East-Iowan, and East-Wisconsin formations.

noteworthy exception seems to be found in the Toronto and Scarboro sections; but no interglacial fossils (excepting near the coast in New Hampshire) are known farther eastward in New York and New England, which are traversed by numerous prominent moraines.

Early Interglacial Lignite on the Missinaibi and Kenogami rivers.—The most noteworthy interglacial beds known in North America, among those which must probably be referred to the time of prevailing ice accumulation, are the layers of lignite, between deposits of till, observed by Dr. Bell in several places on the Missinaibi, a branch of the Moose river, and again on the Kenogami, a branch of the Albany, both tributary to James bay.* During the glacial retreat at the end of the Ice age that area was probably at first occupied by a great glacial lake, receiving for some time the northeastward outflow of lake Agassiz and itself outflowing successively to lakes Warren and Algonquin by channels across the watershed dividing the Kenogami and Missinaibi rivers from lake Superior, to the lake St. Lawrence by the pass near lake Abittibi, and latest by the same pass to the sea in the St. Lawrence and Ottawa valleys. After the sea gained admission to the basin of Hudson and James bays, the ice being then melted from Hudson strait and bay, the glacial lake of the Kenogami, Missinaibi and Abittibi region was succeeded by a less extended marine submergence, which yet covered some of the lower localities of the interglacial lignite. It seems well-nigh certain, therefore, that those lignite layers, varying in thickness up to eight feet, belong to a time of oscillation of the ice-sheet interrupting its accumulation rather than its departure.

Thin seams of interglacial lignite also occur on the head streams of the South Saskatchewan, as reported by Dr. Geo. M. Dawson† and Mr. J. B. Tyrrell;‡ but, although these may be referable to approximately the same time as the Missinaibi lignite, they may perhaps belong to a much later stage of recession, followed by reädvance, of the ice-sheet during the middle or the closing part of the Glacial period.

*Geol. Survey of Canada, Report of Progress for 1877-78, p. 4C; and Annual Report, new series, vol. II, 1886, p. 38G.

†Geol. Survey of Canada, Report of Progress for 1882-83-84, p. 144C.

‡Ibid., Annual Report, new series, vol. II, 1886, p. 143E.

RECORDS OF THE DRIFT CHIEFLY LIMITED TO THE CULMINATION AND DEPARTURE OF THE ICE-SHEET.

Nearly or quite all the other observations of interglacial beds on this continent seem more probably referable to the interval between the Kansan and Iowan stages of extending glaciation, near the middle of the Ice age, and to fluctuations of the general glacial retreat in the declining Wisconsin stage, of which successive steps or substages are indicated by boundaries 2 to 7 on plate X. We are not, however, to infer therefore that alternate decrease and increase of the ice-covered area were more prevalent during the decline than during the oncoming of the Ice age. Extensive glacial erosion and deep drift deposits have destroyed or concealed the far greater part of the records of the beginning and advance of this period to its Kansan stage of culmination. The earlier half of its history is mainly lost. All the moraines, eskers, kames, and valley drift, nearly all the interglacial deposits, and most of the striation preserved on the bed-rocks, belong to the later Kansan time of maximum extension of the ice-sheet upon the interior portion of our continent, and, in much larger measure, to its renewal of growth in the Iowan stage and to its final recession.*

BOREAL AND ARCTIC SPECIES PROBABLY CHARACTERISTIC OF INTERGLACIAL DEPOSITS DURING THE EPOCH OF GENERAL ICE ACCUMULATION.

The conditions producing the abundant snowfall and the resulting ice-sheets of the Glacial period were undoubtedly attended with southward and outward migration of many boreal and Arctic species of animals and plants, which during the Tertiary era had come into existence in the polar regions and on high mountain ranges reaching to altitudes of prevailing cold in more temperate latitudes. Accepting epeirogenic uplifts of the portions of the earth's crust enclosing the North Atlantic ocean as the cause of the envelopment of the continental areas on each side by the Pleistocene ice-sheets, we shall readily see how the cold-loving circumpolar and alpine fauna and flora of preglacial times would spread outward over

*Compare the Twenty-second Annual Report of the Geol. Survey of Minnesota, for 1893, pp. 34, 41; Bulletin, Geol. Society of America, this vol. VI, p. 21; and Prof. T. C. Chamberlin, in "The Great Ice Age" (J. Geikie, third edition, 1894), pp. 753, 754.

all the areas which at the culmination of the uplifts became ice-covered. In the high plateau climate of these lands, their previously temperate species would be driven out or survive only in sheltered valleys, while the greater part of the country would bear forests of the boreal conifers or probably become even too cold for any timber growth, like the "Barren Grounds" of our far northern and Arctic regions and the tundras of Alaska and Siberia. It is therefore probable that the species of interglacial deposits formed during the times of general but fluctuating growth of the ice-sheet must be predominantly boreal and Arctic.

But if any deposit during the stages of general ice accumulation shall be found to contain chiefly or solely species now restricted to temperate regions, they may be regarded as evidence of a geologically sudden uplift and change from a mild climate to deep snow accumulation, yet with some variability of its limits; or, less probably, they may represent some exceptionally sheltered spot where a remnant of the former plant and animal life, surviving the general climatic change, was finally overwhelmed.

Temperate Species of Interglacial Deposits during the Epoch of Ice Departure.

With the subsidence of the ice-burdened lands to their present altitude or lower, which is well ascertained to have been true of the time of departure of the ice-sheets, very different climatic conditions ensued. On the high expanse of the ice there still reigned an Arctic severity of cold. For some time, as shown by Le Conte, the snow and ice accumulation went on faster than the subsidence, causing the maxima of the land depression and the thickness and extension of the ice during its second or Iowan stage of general growth to be nearly contemporaneous. While the central parts of the ice-covered areas had sunk probably four or five thousand feet from their preglacial altitude, the borders of the ice in the northern United States were lowered apparently in general about half as much, thereby sinking closely to their present levels; and this sufficed to turn the balance from glacial growth to a beginning of the final retreat. The summer heat and rains on the glacial boundary, when reduced from its former hight, melted away the ice margin faster than it could be

replenished. This process, after interruption by the Iowan stage of renewed cold and gathering of snow and ice on a large region of the Ohio, upper Mississippi, and Missouri river basins, gradually extended inward, giving steep gradients of the ice-front which formed moraines whenever a series of exceptionally cool years and unusual snowfall allowed any pause or reädvance. The whole ice-sheet, through the continuance of its peripheral melting, disappeared; and meanwhile the land on which it had lain, being unburdened, was moderately reëlevated, in obedience to its law of isostasy, proportionally with the glacial melting and retreat.

The Arctic plants and animals, which had flourished near the borders of the mainly increasing ice-sheet while the land had its great preglacial altitude, could not endure the Late Glacial or Champlain depression of the land and then found refuge only on cold mountain summits, as of the White mountains in New Hampshire, which have about fifty species of otherwise solely far northern and circumpolar plants. Even closely adjoining the margin of the ice-sheet during its departure from the northern United States and southern Canada, the fauna and flora, as shown by the interglacial beds of Toronto and Scarboro' and of southeastern New Hampshire, marking temporary glacial reädvances, were predominantly of the same species which are now found in those temperate latitudes. The warm climate which melted away the ice-sheet from these areas had principally banished the frigid and exclusively northern species and had brought back, as fast as the ice retreated, the vegetation and the animal life that have continued through the Postglacial period to the present day. Evidence of such a general return of warm or temperate climatic conditions, near the boundaries of the ice-sheet while it was receding with occasional wavering oscillations, is afforded by the interglacial beds of the upper Mississippi region and the north side of lake Ontario; and these conditions are now repeated on the border of the Malaspina ice-sheet.

Previous to Russell's observations of this Alaskan piedmont glacier, now being fast melted away, with its formerly englacial drift exposed by ablation on its outer part as superglacial

drift and bearing a luxuriant growth of coniferous forest trees up to three feet in diameter, dense thickets of shrubs, and many herbaceous flowering plants, the occurrence of such temperate species of plants and animals in interglacial beds was commonly accepted as proof of the retreat of the ice-sheet to a great distance and an ensuing long reädvance. It is now seen, however, that any climatic change producing a reädvance of the Malaspina ice-sheet, though only enduring through a few years or decades and sending the border forward to any small extent sufficient to cover portions of its marginal flora and fauna, would be recorded by temperate species enclosed between deposits of glacial drift.* Many of the features of the Pleistocene drift formations in our northern states, especially of the eskers and stratified valley drift, indicate that the recession of this part of the North American ice-sheet, under the warm Late Glacial or Champlain climate, was more rapid than the present retreat of the Malaspina and Muir glaciers, the contrast being probably as great as between the present mean temperature of the Alaskan coast region and that of the upper Mississippi and the Laurentian lakes.

Minnesota and Iowa.—Remnants of an interglacial surface soil, trunks and limbs of trees, deposits of peat, and stratified sand and silt containing fresh-water molluscan shells, at one or several definite horizons, between sheets of till or unmodified glacial drift, are shown by wells and by borings for oil and gas upon an extensive area which stretches from Ohio westward through Indiana and Illinois to Iowa, and thence northwestward through southern Minnesota into South and North Dakota.

The most elaborate study given to any part of this area is by McGee in northeastern Iowa, where the forest bed, from one to five feet in thickness, is found to be practically continuous on tracts ten to twenty miles or more in extent, occurring commonly at the junction of distinct sheets of lower

*More extended comparison of the Alaskan, Greenland, and Antarctic ice-sheets with those of the Glacial period in North America and Europe is presented in the Bulletin of the Geol. Society of America, vol. IV, 1893, pp. 191-204.

and upper till, the latter being usually from five to twenty feet thick.*

Continuing northward into Minnesota, frequent or occasional observations of this forest and peat bed are afforded by wells, as described by Prof. N. H. Winchell, in Fillmore, Mower, and Freeborn counties on the southeastern border of this state, adjoining Iowa, a thickness of peat varying from one to eight feet being found enclosed between deposits of till at depths from 20 to 70 feet below the surface.†

Farther west and north in Minnesota, where I have explored and mapped the drift and its moraines, well sections encountering remnants of these interglacial deposits are very rare, but sometimes several are found within a few miles of each other, testifying to a partial preservation of the old land surface over considerable tracts, to Lyon, Renville, and McLeod counties, 60 to 90 miles north of the Iowa line. Still rarer occurrences of probably the same forest bed are also shown by my records of wells as far northwestward as Fergus Falls and Barnesville. The second of these towns, situated 218 miles north from the northwest corner of Iowa, is the most northern locality where I have evidence of an interglacial bed apparently belonging to the time of glacial recession preceding the Iowan stage or epoch of ice accumulation and extension.

It seems very significant that Barnesville is three miles west of the highest or Herman beach of the glacial lake Agassiz and about 75 feet below it (plate X). Another locality of an interglacial bed, containing many small gasteropod shells beneath 26 feet of till, is in Mitchell township, Wilkin county, Minnesota, also lying within the area of lake Agassiz and nearly 100 feet below its highest beach. If the surrounding country, when these interglacial beds were formed, had the same relative altitudes and slopes of its drainage as at the time of final retreat of the ice-sheet and existence of lake Agassiz, the land in Barnesville and Mitchell must have been incapable of forest growth or swamp deposits, being covered by

*"Pleistocene History of Northeastern Iowa," Eleventh Annual Report, U. S. Geol. Survey, for 1889-'90, Part I, pp. 189-577, with plates II-LXI, and 120 figures in the text: the forest bed being described, with numerous sections, in pages 486-496.

†Geology of Minnesota, Final Report, vol. I, 1884, pp. 313, 363, 390.

an earlier and interglacial lake with outflow southward where lake Agassiz afterward outflowed to the Minnesota and Mississippi rivers, until the outlet was deeply eroded or a very far retreat of the ice-border to the north allowed free drainage to take its course as now to Hudson bay. Under these conditions the growth of an interglacial forest at Barnesville would imply probably three to six times more glacial melting and recession than otherwise would suffice to account for the most northern of these observed interglacial deposits. It therefore seems to me more likely that during the glacial retreat between the Kansas and Iowan stages or epochs of the Glacial period the present basin of the Red river of the North, which was later occupied by lake Agassiz, had a considerably greater altitude than now, retaining a part, probably a large part, of its preglacial elevation, and that it was thus a land surface with southward descent and free drainage along the Minnesota river valley to the Mississippi. The recession of the ice-sheet before its Iowan stage of renewed growth may then have reached only to the southern part of the Red river valley, instead of the great farther distance to Hudson bay which I formerly supposed in writing of these interglacial deposits in the reports of the Minnesota Geological Survey.*

The erosion of numerous and large interglacial stream courses in the early Kansan drift sheet of southern Minnesota and northern Iowa, including the Minnesota river valley and its continuation past Brown's Valley and above the present bed of lake Traverse, channelled there apparently about 50 feet below the general surface of the adjoining country to the level of the Herman or earliest and highest beach of lake Aggasiz,† and the deposition of thick and extensive interglacial beds of sand and gravel observed at widely separated localities along the Minnesota valley,‡ find full explanation in this retreat of the ice-sheet to the vicinity of Barnesville and

*Geology of Minnesota, Final Report, vol. I, 1884, pp. 402, 406, 466, 479-485, 507, 511, 552, 580, 581, 585-6, 609, 625; vol. II, 1888, pp. 138, 186, 187, 199, 466, 529, 555, 662, 668.

†Proc. Am. Assoc. for Adv. of Science, vol XXXII, for 1883, pp. 222-227. Geology of Minnesota, vol. I, pp. 479-485, 507, 580; vol. II, pp. 134, 172, 216, 519-525.

‡Proc. A. A. A. S., l. c. Geol. of Minn., vol. I, pp.581,582,625; vol. II, pp. 131, 171, 172.

Mitchell, Minn., 200 to 250 miles inward from its farthest limits in North Dakota and on the northern boundaries of the Wisconsin driftless area, but 500 miles north from its limits in northeastern Kansas and in Missouri. During its later Iowan stage the ice-sheet reached from Barnesville about 200 miles westward into North Dakota, an equal distance eastward into northwestern Wisconsin and northeastern Minnesota, and some 350 miles or more south-southeastward in Iowa. A marginal moraine, which had been formed probably during a pause or reädvance interrupting the later part of the intermediate glacial retreat, is indicated by exceptionally abundant boulders in a stratum of the drift shown in the bluffs of the upper part of the Minnesota river valley and by its tributaries, overspread by 25 to 50 feet of the later Iowan and Wisconsin till deposits,* according to Chamberlin's classification of these drift formations before cited.

Among the species making up the interglacial forest bed in northeastern Iowa, McGee reports the cedar (*Juniperus virginiana*) as far the most abundant: its other identified conifers are pine, spruce, and tamarack; and its deciduous trees and shrubs comprised species of oak, elm, walnut, hickory, sumach and willow. Its only observed traces of animal life represent an extinct species of horse (*Equus complicatus*), the wood rabbit, and the common skunk.† In southern and western Minnesota, besides the observations of interglacial forest trees and peat, numerous wells have yielded small molluscan shells, considered to be like those of the present lakes and sloughs of the same region, in deposits which here are regarded as synchronous with the principal forest bed, belonging to the time of glacial recession before the Iowan till formation.

Much later, between the times of formation of the Elysian and Waconia or fifth and sixth moraines of the series mapped in Minnesota all of which are referred to the late Wisconsin stage or epoch of the Ice age, I find evidence of a reädvance

*Geol. of Minn., vol. I, pp.626-628, including also notes of the transportation of red till and masses of copper from the lake Superior region to a farther distance southwestward during the Kansan stage than in the later stages of glaciation.

†U. S. Geol. Survey, Eleventh Annual Report, p. 495.

of the ice-front at Chaska, Minn., in the lower part of the Minnesota valley, across beds of stratified clay containing large *Unionidæ* shells, in such topographic and stratigraphic position that these mollusks are shown to have become already well established there in a congenial habitat, with favoring climatic conditions, while the ice was receding between these late marginal moraines.* The forest bed and associated molluscan shells before noted record a great interval of glacial retreat and reädvance, measured by hundreds of miles; but the Chaska fossils doubtless represent only a small oscillation, probably no more than a few miles and possibly even less than one mile.

Northwestern Illinois.—Recent studies of the Pleistocene formations in the basin of the Pecatonica river, in northwestern Illinois, by Mr. Oscar H. Hershey,† show that the molluscan fauna living there in creeks and rivers during the latter part of the interval following the Kansan formation and preceding the Iowan formation, which was accompanied by extensive loess deposits, comprised, so far as it is represented by a collection of six species, only the same shells which are still abundant in the fresh waters of northern Illinois to-day. The many air-breathing and fewer fresh-water molluscan species in the loess have also all continued to live in the same region to the present time. Mr. Hershey's paper is of special interest in proving that after the growth of forests and the existence of mollusks betokening a climate nearly the same as now, while the conditions of gravel and sand deposition in the valleys implied a slightly higher general altitude of the country, there ensued a great depression toward the end of the Iowan time of reädvancing glaciation and during the closely following glacial retreat with its abundant deposition of loess. This depression is thought to have been near the end of the Glacial period. In another paper,‡ Mr. Hershey estimates that the cutting of certain rock gorges in the same district, referred to the time between the Kansan and Iowan formations as these are subsequently named by Chamberlin, required this interval to be much longer than the Postglacial

*Geology of Minn., vol. II, pp. 131-134, 141-144.

†AM. GEOLOGIST, vol. XV, pp. 7-24, Jan., 1895.

‡AM. GEOLOGIST, vol. XII, pp. 314-323, Nov., 1893.

period or to have had far more favorable conditions for stream erosion.

Southern Illinois, Indiana, and Ohio.—The earliest records of observations of interglacial forest beds in Ohio and other states farther west were made thirty years ago by Whittlesey; and the reports of the several state geological surveys since published contain plentiful notes of the occurrence of these beds between deposits of till, summaries of which have been included by several authors in their discussions of the drift.* The most recent of these discussions is by Leverett, who has traced a large series of marginal moraines through these states. His paper, accompanied by a map of the moraines in eastern Indiana and western Ohio, enumerates the glacial and interglacial stages in their order as follows.

1. A glacial stage during which the ice-sheet extended farther south in this region than in any later stage.

2. A long stage of deglaciation marked by development of soil and by attendant oxidation, leaching, and erosion of the drift.

3. A stage of silt deposition during which the highest points in southwestern Ohio apparently became covered at flood stages. The region then stood probably several hundred feet lower than now. From evidence gathered farther west, the silt deposition seems to have accompanied a glacial stage whose deposits are concealed in this region by later drift sheets.

4. A glacial stage, during which the outermost well-defined frontal moraine was formed, with as good attendant drainage as is now afforded in the western Ohio region. The drift of this stage is concealed in eastern Ohio by the later moraines. The main streams at the time of this glaciation flowed at levels 200 feet or more below the level of the upland soil.

5. A stage of deglaciation of considerable length, with altitude somewhat as at present, indicated by valley excavation.

6. A glacial stage characterized by sharply indented morainic ridges, with such elevation and slopes of the land as to give more vigorous drainage than now, not only in Ohio, but as far to the west as the moraine has been correlated. The ice-sheet reached about to the glacial boundary in eastern Ohio, but fell short many miles of reaching the boundary farther west.

*Charles Whittlesey, Smithsonian Contributions, No. 197, vol. xv, 1864, pp. 13-15.

J. S. Newberry, Geology of Ohio, vol. II, 1874, pp. 30-33.

N. H. Winchell, Proc. Am. Assoc. for Adv. of Science, vol. xxiv, for 1875, Part II, pp. 43-56.

G. F. Wright, The Ice Age in North America, 1889, pp. 475-496.

Frank Leverett, Journal of Geology, vol. I, pp. 129-146, with map, Feb.-March, 1893.

7. A glacial stage characterized by morainic ridges of smooth contour. This stage embraces the final disappearance of the ice-sheet from Ohio. A deglaciation interval is believed to have preceded it, but decisive evidence in support of this view is not obtained. During the formation of these later moraines the land had an altitude similar to that of to-day.

The first of these time divisions seems to the present writer to be the Kansan stage; the second, the interval between the Kansan and Iowan stages, including the growth of the forests which form the principal interglacial forest beds; the third, the time of land depression and retreat of the ice-sheet, with deposition of its Iowan till and loess, after its Iowan stage of increased area, the silt in Ohio being contemporaneous with the loess in the Mississippi and Missouri valleys; and the fourth to the seventh, successive parts, comparatively short, constituting together the Wisconsin or closing stage or epoch of the Ice age in the northern United States, according to its subdivision proposed by Chamberlin. The depth of the leaching by which the calcareous matter of the interglacial soil and subsoil in Ohio and westward was removed during the interval between the Kansan and Iowan stages is found by Mr. Leverett to be seldom less than six or eight feet, while the present soil is rarely leached to so great a depth as six feet. In both cases the measurements are in till of closely similar character. An earlier paper by Mr. Leverett* gives the distance of the interglacial recession known by this ancient soil and the accompanying forest bed as not less than 250 miles to the north from the southern margin of the drift in Illinois, and nearly 150 miles to the north from the outermost moraine of the newer drift.

Toronto and Scarboro, Ontario.—An excavation in the stratified drift and till for brick-making beside the Don river in the suburbs of Toronto, on the northwest coast of lake Ontario, recently described by Prof. A. P. Coleman,† has yielded many fresh-water mollusks and wood of three species of trees. The mollusks, as determined by Dr. W. H. Dall and Mr. C. T. Simpson of the Smithsonian Institution, comprise *Pleurocera*

*Proc., Boston Society of Natural History, vol. XXIV, pp. 455-459, Jan. 1, 1890.

†AM. GEOLOGIST, vol. XIII, pp. 85-95, Feb., 1894. The following discussion of this paper was contributed to the Glacialists' Magazine, vol. I, pp. 236-240, June, 1894.

subulare, *P. elevatum*, and perhaps *P. pallidum*; *Valvata sincera*; *Sphærium striatinum*; *Unio phaseolus*, *U. clavus*, *U. pustulosus*, and its var. *schoolcrafti*, *U. occidens* (?), *U. luteolus*, *U. undulatus*, *U. rectus*, *U. trigonus*, and *U. solidus*. All the species are still living, but at least three of the Unios and one Pleurocera appear to be now restricted to waters tributary to the Mississippi and are not known in the present fauna of the St. Lawrence drainage area. The three trees whose driftwood occurs in the same layer with these shells, are identified by Prof. D. P. Penhallow of McGill University, Montreal, as probably *Fraxinus quadrangulata*, *Quercus obtusiloba*, and *Taxus baccata*, var. *canadensis*. The first and second are common now in portions of southern Ontario, but not farther northward, while the third occurs throughout the greater part of Canada. The section supplying these fossils includes the following beds in descending order:

	Feet
Sandy soil, followed by brownish gray clay with boulders	3
Stratified bluish gray calcareous clay (making buff-colored brick)	69
Brownish or drab clay, much jointed (making red brick)	11
Brownish yellow stratified sand	4
Blue calcareous clay, with peaty flakes	3
Brown sand and gravel, showing false bedding, with thin layers of blue or brown clay—fossiliferous	18
Blue boulder-clay (till) with striated boulders	3
Hudson River shales, quarried to make dark red pressed brick	30
Total	141

The base of the section is at the level of the river, which is nearly that of lake Ontario, 247 feet above the sea. Immediately above the lower boulder-clay, at a height of 280 to 298 feet above the present sea level, the fossil shells and wood were found; and evidently the Unios in the lower part, resting directly on the till, occupy the place where they were living, since they have not been waterworn, but retain their dark epidermis, and often have the two valves united.

These observations are believed by the present writer to show that the ice-dammed lake Iroquois, the Late Glacial or Champlain representative of lake Ontario, stood first, when drainage was obstructed by the ice-sheeet at boundary 5, plate X, at a level not more than 30 or 40 feet above the present lake. There next ensued, probably, a gradual rise of the lake, due to an uplifting of the country about its outlet at Rome, in central New York, flowing to the Mohawk and Hud-

son, until it stood at the level of the well defined Iroquois beach, traced by Spencer and Gilbert, which has a height at Toronto of almost 200 feet above lake Ontario. Thick fossiliferous delta deposits had been meanwhile brought into the north edge of the lake at Toronto and several miles eastward along the lake-cliff section of Scarboro' Heights; and repeated reädvances of the ice front, one during and the other after the delta accumulation, formed at the locality last noted two deposits of till or boulder clay.

The drift beds making the Scarboro' Heights, six to fifteen miles east of Toronto, are given, in their descending order, by Mr. George J. Hinde, as follows:*

	Feet.
Postglacial stratified sand and gravel	50
Till or boulder-clay, No. 3	30
Interglacial laminated clay and sand	90
Till or boulder-clay, No. 2	70
Interglacial fossiliferous sand	40
Interglacial fossiliferous clay	100
Till or boulder-clay, No. 1, elsewhere seen in the vicinity of Toronto with a thickness of 25 feet, lies here below the lake level.	

During all the time in which the basal stratified clay and sand, together 140 feet thick, were being laid down, fragments of plants were deposited in them, the most abundant being mosses of the genera *Bryum*, *Fontinalis*, and *Hypnum*. The other plant remains of these beds comprise a *Chara*, *Lycopodium* spores, wood of pine or cedar, rush leaves, and various seeds. Fossil shells are wellnigh absent, including only a *Planorbis* and, doubtfully, a *Zonites*.

Mr. Hinde's collections further included a very remarkable representation of the insect fauna, of which Mr. S. H. Scudder writes:†

Among the material found by him was a considerable number of the elytra and other parts of beetles, an assemblage indeed larger than has ever before been found in such a deposit in any part of the world, and they are mostly in excellent condition. Twenty-nine species have been obtained, some of them in considerable number. Five families and fifteen genera are represented; they are largely Carabidæ......The next family in importance is the Staphylinidæ......Not one of them can be

*Canadian Journal, vol. XV, pp. 388-413, April, 1877.

†"Tertiary Insects of North America," U. S. Geol. Survey of the Territories (F. V. Hayden in charge), vol. XIII, 1890, pp 40, 41.

referred to existing species, but the nearest allies of not a few of them are to be sought in the Lake Superior and Hudson Bay region, while the larger part are inhabitants of Canada and the northern United States, or the general district in which the deposit occurs. In no single instance were any special affinities found with any characteristically southern forms, though several are most nearly allied to species found there as well as in the north. A few seem to be most nearly related to Pacific forms, such as the Elaphrus and one each of the species of Platynus and Pterostichus. On the whole, the fauna has a boreal aspect, though by no means so decidedly boreal as one would anticipate under the circumstances.

It seems quite certain that the fossiliferous beds of these two localities were approximately contemporaneous, and that the glacial reädvances pushing westward and forming the two thick boulder-clay deposits in Scarboro' brought only thin and discontinuous boulder-clay beds in Toronto. Much of the stratified clays, sand, and gravel, may have come from englacial drift of the neighboring ice-sheet on the northeast, being brought by streams from its melting; while the driftwood and leaves of trees, and mosses of peat bogs, growing within a few miles westward, were contributed to the same deltas by streams flowing from a wooded land area bordering the ice, such as Russell found adjoining the Malaspina ice-sheet in Alaska and even extending its forest growth several miles upon the drift-covered margin of the departing ice. The glacial retreat from the northern United States and southern Canada, after the culmination of the depression of the land, with which the Iowan stage of glaciation terminated, is known to have been geologically very rapid; and the warm climate which caused the ice-sheet to be fast melted away appears to have permitted a temperate fauna and flora, similar to those now found in the same latitude, to follow close upon the retiring ice-border. Another excavation in the Toronto drift has supplied a maple leaf named *Acer pleistocenicum* by Prof. Penhallow, and wood which he identifies as *Asimina triloba* and *Ulmus recemosa*, species which now have their northern limits in the southern part of the Province of Ontario. When the land had its Preglacial and Glacial high elevation, a severe climate prevailed along the border of the ice-sheet at its times of growth; but with the depression of the country beneath the ice burden, a great change to nearly the present climatic conditions along the glacial boundary caused it to

recede rapidly northward and be immediately followed by fertility of vegetation and of animal life.

At a somewhat later time than that represented by the Toronto and Scarboro' fossiliferous modified drift, when the ice-sheet had so far receded as to uncover the Ottawa and St. Lawrence valleys, which then became filled with the far more extensive Gulf of St. Lawrence to lake Champlain, almost to the mouth of lake Ontario, and to Allumette island of the Ottawa river, 75 miles above the city of Ottawa, the presence of a flora including forests, and a marine fauna, nearly like those of to-day in the St. Lawrence region, is known, as so fully described by Sir William Dawson in his recent work, "The Canadian Ice Age," and in his many earlier papers, by their remains in the Leda clays and Saxicava sands, deposited during the short interval between the glacial retreat and the reëlevation of the land from its Champlain subsidence.

In a limited sense the Toronto fossils may be called interglacial, as the term is used in the present paper, since they lie between deposits of glacial drift; but they seem better referred to moderate oscillations of the ice boundary, during its general retreat after the Iowan stage, that is, to a time during the Wisconsin or moraine-forming stage, rather than to the distinct glacial epochs which Coleman infers from them. Both these beds and the richly fossiliferous Leda clays, which last everywhere overlie the latest glacial drift, may be referred to the Champlain or closing epoch of the Ice age; and they both testify of the close sequence of a warm climate, with luxuriant plant and animal life, immediately after the ice retreated.

Professor Chamberlin, writing of these Toronto and Scarboro' interglacial fossiliferous beds since my study as given in the foregoing paragraphs but previous to its publication, has referred them provisionally to the interval between his Iowan and Wisconsin glacial drift formations; and he thinks that a reädvance of the ice-sheet to the most western and southern of the Wisconsin series of marginal moraines drove out the mollusk species which were mentioned as now limited in their geographic range to the Mississippi river basin.* Concerning this hypothesis, it is to be remarked that we have nowhere

*"The Great Ice Age," third ed., 1894, pp. 765-769.

else evidence of any great reädvance of the ice front, to the extent of hundreds of miles which would be so required, at any time subsequent to the Iowan stage. Only during the interval preceding that great renewal of ice accumulation have proofs of such extended oscillations of the ice border been ascertained, and these are areally limited, if we except the localities at and near Toronto, to the upper Mississippi basin from Ohio west to the Dakotas. From the Scioto river in central Ohio eastward 700 miles, to the Atlantic ocean south and east of New England, the moraines of the Wisconsin drift formation lie on or near the southern limit of glaciation. Toronto lies far within this area which is almost wholly occupied by the late drift, and no other observations of allied interglacial deposits, like the plentiful and far spread notes of the forest beds farther west, are reported within the eastern area. Therefore it seems to me more probable that the ice-sheet was melted away from the region of the upper Laurentian lakes as far eastward as to Toronto, while yet it remained on the northeastern part of the basin of lake Ontario, on northern New York, and the greater part of New England;* and that some species of the fauna so first coming into the region of Toronto were later compelled to retreat farther west when brought more fully into competition with the eastern fauna of the coastal region. The very rapid evolution now in progress producing the exceedingly abundant species of insects is somewhat surprisingly shown by the changes, or less probably the extinction, of all the twenty nine species of beetles found in the Scarboro' delta deposits, whereas all of the numerous fresh-water mollusk species in the Toronto section are still living and unchanged.

The evidence of two closely consecutive glacial recessions and reädvances in Scarboro', and the thinning out of the thick deposits of till so formed within a few miles westward, imply that the ice border during that whole time was near, but seem quite inexplicable on the hypothesis that these till formations record great reädvances of the ice, as either to the Iowan stage or to the Wisconsin moraines. Furthermore, the

*Am. Geologist, vol. xiv, pp. 62-65, July, 1894. Am. Jour. Sci., III, vol. xlix, pp. 1-18, with map, Jan., 1895.

thick Scarboro' stratified beds were evidently amassed as a delta, probably too in a lake of gradually rising level, and the origin of so large a supply of sediments seems referable only to their derivation chiefly from englacial drift exposed by ablation on the margin of ice-fields within the drainage area of the delta-forming streams. In this tract of confluence between the great eastern and central lobes of the Laurentide ice-sheet, represented by the angle of the drift boundary at Salamanca in southwestern New York (plate X), there undoubtedly was brought an exceptional volume of the englacial drift by the confluent glacial currents.

New England and New Brunswick.—In all the region eastward from Toronto fossiliferous beds recording glacial oscillations are known to me only in southeastern New Hampshire, a few miles back from the present seashore, where white pine trees grew and bore cones, and the common marine mussel (*Mytilus edulis*) existed, close to the waning border of the ice-sheet, which made a short reädvance covering these fossils;* and in the neighborhood of St. John, N. B., on the shore of the Bay of Fundy, where Chalmers describes alternating deposits of unstratified boulder-clay, or till, and stratified clay with a few pebbles and boulders, both occasionally containing *Yoldia arctica* in abundance, while several other species of shells are less frequent or rare.†

Chalmers shows that the St. John interglacial beds were formed at or near the margin of the ice-sheet, and beneath the level of the sea, when the land relatively stood 100 to 200 feet or more below its present hight. Several times of local retreat and reädvance of the ice-front are clearly indicated. The shells of the stratified portions are *in situ*, but the till encloses littoral species which were probably pushed forward by the ice and mingled with the deep-water forms. All the species belong to the present arctic or subarctic marine fauna, and this *Yoldia*, now restricted to polar seas, thrives especially near the mouths of muddy streams flowing from glaciers.

In the till of drumlins near Boston Prof. W. O. Crosby and Miss Hetty O. Ballard have very recently noted rare glaciated

*Warren Upham, Geology of N. H., vol. III, 1878, part III, p. 163.

†Bulletin, Geol. Society of America, vol. IV, 1893, pp. 361-370.

calcareous nodules, containing shell fragments, which they regard as evidence of some glacial recession and reädvance.* It seems to me possible, however, in view of the absence of other indications of glacial oscillation there, that the formation of the nodules took place in superglacial drift exposed by ablation on the ice surface and afterward covered by increasing snow and ice accumulation and onflow, but requiring no readvance of the glacial boundary.† Another and more probable explanation, as I think, is that these rare nodules, like the abundant fragments of marine shells in the same till, are referable to the early Pleistocene time when the area of Massachusetts bay is known by these shells to have had nearly its present relations to the sea level, and to the succeeding time of great epeirogenic uplift of this region and of all the northern half of this continent, to which the Hudson and Californian submarine fjords and the subaërial erosion contour of the now submerged Fishing Banks between Cape Cod and Newfoundland bear witness.‡ During this uplift, before it had culminated in the Glacial period, leaching waters percolating through the shell beds may have formed hard calcareous layers which were eroded and broken up by the ice-sheet to yield the glaciated nodules of the till.

All the fifty-five species whose shell fragments are identified in the drumlins of Boston and its vicinity are still living. They include no exclusively northern species, but indicate that the sea had even a somewhat warmer temperature than now in Massachusetts bay. If this reference of their origin to beds antedating an epeirogenic movement which caused ice accumulation in that district is true, they give very impressive testimony of the geologic brevity of the Glacial period. The same is also to be said of the similarly large representation of the early Pleistocene marine fauna which is preserved in sections underlying the outer morainic margin of the drift in

*Am. Jour. Sci., III, vol. XLVIII, pp. 486-496, Dec., 1894.

†Compare my paper on "Conditions of Accumulation of Drumlins," AM. GEOLOGIST, vol. X, pp. 339-362, Dec., 1892.

‡AM. GEOLOGIST, vol. VI, pp. 327-339, Dec., 1890, Am. Jour. Sci., III, vol. XLVI, pp. 114-121, Aug., 1893. Proc. Boston Society of Natural History, vol. XXVI, 1893, pp. 42-48 (also in Am. Jour. Sci., III. vol. XLVII, pp 123-129, Feb., 1894).

Sankoty head on the east shore of Nantucket* and in Gardiner's island.† So recent was the Ice age that none of these preglacial molluscan species have become extinct, nor, with very rare exceptions, undergone any noteworthy change.

DIVISION OF THE GLACIAL PERIOD IN THE GLACIAL AND CHAMPLAIN EPOCHS.

Seeking to subdivide the Ice age with reference to its dynamic causes and its secular fluctuations in climatic conditions, we find, first, a long epoch of general snow and ice accumulation, interrupted, at least locally and temporarily in its early part by moderate oscillations of the glacial boundary, and including, after the ice-sheet attained its maximum Kansan stage in the Mississippi basin, a long interval of extensive retreat of that part of the ice-sheet, followed by renewal of its growth until it again reached far south toward its former limits. This part of the Ice age is well denominated, from its envelopment of the land by ice-sheets, the Glacial epoch. Its chief cause I think to have been uplifts of the glaciated regions thousands of feet above their present height. Its grand subdivision in the Kansan, Interglacial, and Iowan stages, may have been due to the climatic effects of the last two passages in the precession of the equinoxes, with accompanying nutation, bringing the winters of the northern hemisphere in aphelion about 30,000 years ago and again about 10,000 years ago. The intermediate time of the earth's northern winters in perihelion would be the stage of great retreat of the ice margin in the upper Mississippi region; but eastward, from Ohio to the Atlantic coast, there appears to have been comparatively little glacial oscillation.‡ This explanation accords with Prof. N. H. Winchell's computations from the rate of reces-

*Desor and Cabot, in the Quarterly Journal of the Geological Society, London, vol. v, 1849. pp. 340-344, partly quoted by Packard in Memoirs, Boston Soc. Nat. Hist., vol. I, pp 252-3. Verrill and Scudder, Am. Jour. Sci., III, vol. x, pp. 364-375, Nov., 1875.

†Sanderson Smith, in Annals of the Lyceum of Natural History of New York, vol. VIII, 1867, pp, 149-151. F. J. H. Merrill, in Annals of the N. Y. Academy of Sciences, vol. III, 1886, p. 354, with sections on Plate XXVII.

Also see papers by the present writer. Am. Naturalist. vol. XIII, pp. 489-502, 552-565, Aug. and Sept., 1879: Am. Jour. Sci., III, vol. XVIII, pp. 81-92, 197-209, Aug. and Sept., 1879; Proc. Boston Soc. Nat. Hist., vol. XXIV, pp. 127-141, Dec. 19, 1888 (also in Am. Jour. Sci., III, vol. XXXVII, pp. 359-372, May, 1889).

‡J. D. Dana, Am. Jour. Sci., III, vol. XLVI, pp. 327-330, Nov., 1893.

sion of the falls of St. Anthony for the Postglacial or Recent period.* and with his estimate of the duration of the interglacial stage from the now buried channel which appears to have been then eroded by the Mississippi river a few miles west of the present gorge below these falls.†

Next ensued, initiating the second and shorter final epoch of this period, a widely extended depression of the ice-burdened land, until mostly it had somewhat less altitude than now. Temperate and warm climatic conditions on the ice border, nearly as now on the same latitudes, then melted away the ice rapidly; its till and loess were deposited in the recession from the Iowan stage; the partially unburdened land began to rise by a moderate uplift, approximately proportional to the glacial melting and nearly keeping pace with it; and conspicuous belts of morainic drift were amassed whenever the steep waning ice-front slackened its departure, or halted, or for any short time reädvanced. This general but fluctuating retreat of the ice-sheet, constituting the Wisconsin stage, divisible into minor stages as shown in plate X, uncovered all the country and was the closing or Champlain epoch of the Ice age, so named from the marine beds in the basin of lake Champlain and along the St. Lawrence and Ottawa valleys, by which the vertical extent of the subsidence terminating the Glacial period and of the succeeding reëlevation is measured.

The following table, from my recent discussion of the time divisions of the Quaternary era,‡ shows the relation of the Glacial period to the earlier and later parts of this era, the arrangement being in the descending stratigraphic order of their geologic formations.

Periods and Epochs of Quaternary Time.

PSYCHOZOIC DIVISION	RECENT PERIOD......	Recent or Present epoch. Terrace epoch.
PLEISTOCENE DIVISION	GLACIAL PERIOD......	Champlain epoch. Glacial epoch.
	LAFAYETTE PERIOD...	Epoch of great elevation and erosion. Lafayette epoch.

*Geol. and Nat. Hist. Survey of Minnesota, Fifth An. Rep., for 1876, pp. 175-189: Final Report, vol. II, 1888, pp. 313-341, with fifteen plates (views showing recent changes of the falls of St. Anthony, and maps). Quart. Jour. Geol. Soc., London, vol. XXXIV, 1878, pp. 886-901.

†AM. GEOLOGIST, vol. X, pp. [illegible], with three plates (sections and a map), Aug., 189[illegible].

‡Am. Naturalist, vol. XXVIII, [illegible], Dec., 1894.

From the review of the glacial and interglacial stages shown by interbedded till and fossiliferous formations in North America, which has been attempted in this paper, the relationship of the minor time divisions of the Glacial and Champlain epochs, under the helpful new nomenclature of Chamberlin, may be formulated provisionally as follows, the order, as in the former table, being that of the stratigraphy, so that for the advancing sequence in time it should be read upward.

Epochs and Stages of the Glacial period.

CHAMPLAIN EPOCH (Land depression; disappearance of the ice-sheet; re-elevation of the land.)	WISCONSIN STAGE (Progressing re-elvation.)	Moderate re-elevation of the land, advancing as a permanent wave from south to north and northeast; continued retreat of the ice along most of its extent, but its maximum advance in southern New England, with fluctuations and the formation of prominent marginal moraines; great glacial lakes on the northern borders of the United States; slight glacial oscillations, with temperate climate nearly as now, at Toronto and Scarboro'; the sea finally admitted to the St. Lawrence, Champlain, and Ottawa valleys; uplift to the present hight completed soon after the departure of the ice. (The Great Baltic glacier, and European marginal moraines.)
	CHAMPLAIN SUBSIDENCE.......	Depression of the ice-covered area from its high Glacial elevation; retreat of the ice from its former Iowan limits; abundant deposition of loess.
GLACIAL EPOCH (Ice accumulation, due to the culmination of the Lafayette epeirogenic uplift.)	IOWAN STAGE.....	Renewed ice accumulation, covering the forest beds and extending south nearly to its early boundary. (Third European glacial stage.)
	INTERGLACIAL STAGE	Extensive glacial recession in the upper part of the Mississippi basin; cool temperate climate and coniferous forests up to the waning ice border; much erosion of the early drift.
	KANSAN STAGE....	Maximum extent of the ice-sheet in the interior of North America, and also eastward in northern New Jersey. (Maximum glaciation in Europe.)
	UNDETERMINED STAGES of fluctuation in the general growth of the ice-sheet.	Including an early glacial recession and reädvance in the region of the Moose and Albany rivers. (First glacial stage in the Alps.)

[CRUCIAL POINTS IN THE GEOLOGY OF THE LAKE SUPERIOR REGION. NO. 3.]

THE ERUPTIVE EPOCHS OF THE TACONIC OR LOWER CAMBRIAN.

By N. H. WINCHELL, Minneapolis, Minn.

It is desired here to make it plain that the eruptive rocks of the Taconic, or Lower Cambrian, can hardly be confounded with those of the Archean. There may be some difficulty in distinguishing the one from the other in England and Wales,

but there is little or none in America. In the Archean, or in other words, in the *fundamental complex* which lies below the great non-conformity, may be seen a great series of basic eruptives. In general they are known as the "greenstones." They fade out into chlorite schists, to silky sericitic schists, and to clay slates. They also become agglomerates and conglomerates, the pebbles of which cannot be referred to any adjacent formation as their source.* This volcanic mass, in Minnesota, when it is compact and destitute of proof of sedimentary structure, rises to considerable altitude above the surrounding country, forming a continuous ridge or range of low mountains, and has been named *Kawishiwin*. It is apparently the latest of the Archean formations. It is involved with the rest of the Archean in upheaval and pressure, and on it lies the base of the Taconic in the same non-conformable attitude as on the gneiss or granite of the other parts of the Archean. It is in this greenstone that occurs the hematite ore of the Vermilion range. There are in addition to these greenstones many acid eruptives, such as granites and felsytes, the nature and origin of which need not be here considered.

The Taconic basic eruptives are very different. They have not been subjected to the upheaval and shearing which the Archean eruptives have suffered. They are freshly crystalline, or beautifully amygdaloidal. They have been both effusive-eruptive and plutonic. They are as laccolites in the slates, making dikes and sills in the strata, and as surface flows and sedimentary ash.† Their date is positively later than the Archean and earlier than the Olenus horizon. They are of two distinct epochs, and they continued active during very long periods. They appear in the Taconic from the eastern part of the United States westward to the northern side of lake Superior and to the Arctic shores. In some places they have been considered Archean, in others Cambrian, in others they have been covered by a new mantle, an ambiguous and unnecessary nomenclature. But in all cases they bear a lithologic stamp, or group of petrographic characters, by which they can be distinguished from the Archean, and in most cases

*Compare "The Origin of the Archean Greenstones" by the writer, in 23d annual report of the Minnesota survey.

†C. R. Van Hise, Bull. Geol. Soc. Am., vol. iv, p. 435, 1893.

their stratigraphic place is determinable from the attendant physical structure.

It is hardly necessary to enumerate categorically the kinds of igneous rock which are found in the Taconic. Broadly speaking they are as a group such as are not found in any other geological horizon. They are illustrated by the eruptives at Cortlandt, in the valley of the Hudson, in the so-called upper Laurentian of the Adirondacks, the upper Laurentian of the region of Ottawa and in other places in Canada, and typically by the great Keweenawan series of the Lake Superior region.* They are also as fairly represented by the eruptives of the copper range which extends northward through the "eastern townships" of Canada from the Vermont state boundary toward Quebec, and by the copper and associated felsytes of the South Mountain region in southern Pennsylvania. That these can petrographically be included in the same class or classes, distinct from eruptives of earlier or later date, there is abundant reason to affirm. It would, however, be sufficient for our purpose here to simply call attention to the non-existence of such rocks in any earlier, or Archean, terrane, since it is only in the Archean that they can be found a place if excluded from the Taconic.

It may be well at this place to mention some of the data on which this generalization is based. If it be admitted that as a petrographic group of igneous rocks a similar assemblage may be found in each of the places mentioned, it will only be necessary to adduce the evidence of their having essentially the same age.

Beginning with the eruptives of the Cortlandt series, which have been described by Dr. Geo. H. Williams,† there is good reason to consider them as post-Taconic. This rests on the authority of Prof. J. D. Dana, who, at intervals, for several years, laboriously traced the Taconic rocks from southern Vermont to Cortlandt and to New York city. At Cortlandt he

---

*Van Hise says: "Quartz porphyry and certain phases of the basic eruptives have been found nowhere but in the Keweenaw series." This is rather broad, and is interpreted to mean nowhere in the Lake Superior region. With this limitation even it might not be admitted by some who have reported felsyte and quartz porphyries in the Keewatin and in the Animikie. See Mon. XIX, U. S. Geol. Sur., p. 462.

†Am. Jour. Sci., Norites of the Cortlandt series, vol. XXXIII, pp. 138, 191, 243, 1887.

found them greatly changed, broken and involved with certain eruptives. It matters not that he considered, at that time, that the sedimentary strata which he had been studying were of the age of the Trenton and Hudson River (Lower Silurian), for he distinctly affirmed that they were geographically continuous from Rutland, Vermont, to New York city. The particular strata here referred to are the Stockbridge limestone and its associated schists, and the granular quartz, and also the Georgia or magnesian slates of the Taconic Mountain range.* It is sufficient to say that these several parts of the original Taconic of Dr. Emmons have since then been shown to be of Lower Cambrian age, by the discovery of characteristic fossils by officers of the United States Geological Survey, at many places in Vermont and eastern New York.†

These sedimentary rocks, bearing their acquired crystalline petrographic characters, continue further southwest, entering New Jersey. They are also affected by a similar intrusion of eruptive rock at Rosetown, N. Y. In New Jersey they have afforded Olenellus,‡ and at Rosetown the eruptives are considered by J. F. Kemp§ as "later than the Tompkins Cove limestone," whose Cambrian age "seems to be increasingly probable." It should be remembered that until these discoveries were made these sedimentary rocks, whose texture is sub-crystalline and crystalline, and which consist of gneiss, quartzyte, mica schist, marble and magnetite iron ore, had been believed to be Archean, and had been so mapped generally. They differ, however, from the true Archean. They extend into the Adirondacks, westwardly from the Vermont area, carrying their characteristic structural and petrographic features. One of their most noticeable strata is the white marble. This is extensively wrought in Vermont and on the northern slopes of the Adirondacks, as well as in New Jersey.

That there are two crystalline series in the Adirondacks has long been known, although in default of careful study the

---

*Am. Jour. Sci., many papers from 1880 to 1887.

†WALCOTT, Bulletin 30, U. S. Geol. Sur.; J. E. WOLFF, Bull. Geol. Soc. Am., vol. II, 1891, pp. 331-337; T. NELSON DALE, Bull. Geol. Soc. Am., vol. III, p. 514, 1892.

‡F. L. NASON, Geol. Sur. of New Jersey, for 1890. The post-Archean age of the white limestones of Sussex Co.

§Am. Jour. Sci., (3), XXXVI, pp. 247-253, 1888.

whole region has very generally been mapped as Laurentian, following the original designation of Logan and the New York survey. Dr. Emmons was the first to call attention to the later date of the "hypersthene rock." He says:*

"We know that the Hudson River series [i. e. what is now considered the Georgia slates of the Taconic.—N. H. W.] is distributed along the eastern base, or northeastern termination of some of these ranges; an event which may have happened very soon after their deposition, or at a still later period."

In 1876 Prof. James Hall dissented from the prevalent idea that the marbles of the Adirondacks were of Laurentian age. He recognized two non-conformable portions of the so-called Laurentian, in the Adirondacks, but he asserts distinctly that "the limestone of that neighborhood (Fort Henry and Westport) did not form a part of the lower Laurentian series of strata, but unconformably overlaid the upturned edges of the gneissic beds of that portion of the system."† Neither does this limestone conform to the upper, or labradorite, portion of the system. The upper portion, being composed, in his idea, "of massive beds of labradorite rock," and other granite rock, both being of irruptive origin, would hardly be expected to conform to the limestone. In this respect the crystalline limestones of the Adirondacks furnish an exact parallel, in their structural relations with the basic eruptives, to the limestones at Stony Point and Rosetown, a part of the well-known Cortlandt series.

The Adirondack gabbros, therefore, have to be made to conform, in date, to two leading facts.

1. They are earlier than the Potsdam sandstone (at least the Olenus horizon) which lies upon the "hypersthene rock," according to Emmons and later observers.

2. They are later than the marbles and quartzyte, the marbles and quartzyte having furnished Lower Cambrian fossils in several places in Vermont closely adjacent.

Whether they are earlier than the Middle Cambrian, as well

---

*Geol. of New York, Second district, 1842, p. 207.

†Note on the Geological position of the serpentine limestone of northern New York, and an inquiry regarding the relations of this limestone to the Eozoon limestones of Canada. Am. Jour. Sci., (3), XII, p. 298, 1876.

as the Olenus zone, there is not sufficient evidence to warrant a judgment, although there is some evidence, which need not be entered upon here, to show that the earliest eruption, which was presumably that of the main gabbro mass, was before the Paradoxides epoch, and may have been the cause of the destruction of the Olenellus fauna.

Many other geologists have reached the conclusion that two series of crystalline rocks exist in the Adirondack area. Vanuxem, in 1842, distinctly states that in Lewis county he referred certain metamorphic rocks to the Taconic system, (Report on the Second district, p. 135). T. B. Brooks, in 1873, called attention to sub-crystalline strata below the Potsdam sandstone in St. Lawrence county, which he suggested belonged to the Taconic system (Am. Jour. Sci., (3), IV, p. 22, 1872). The whole series observed by Brooks between the Potsdam and the gneiss was considered to aggregate 700 feet, but he did not find the bottom beds. A. R. Leeds in 1878 referred the rocks of Essex county to the Norian system, which has been shown to be upper Laurentian (Thirteenth report of the New York state museum, pp. 79-109, 1878). C. E. Hall reached results similar. He attempted to express the stratigraphic order of the parts (Twenty-second report of the New York state museum, 1879, and the Fourth report of the State Geologist, 1884), viz.: (1) Limestones (verd-antique marbles, plumbago, etc.) and the Labrador series, or upper Laurentian, with its titanic ores, certainly non-conformable with the lower Laurentian and probably with the upper Laurentian. (2) Laurentian or sulphur ore series, essentially a series of quartzytes with dependent gneisses, associated with the labradorite rocks as a part of the upper Laurentian. (3) Lower Laurentian or magnetic iron ore series. Mr. Hall was not satisfied as to the stratigraphic position of the "sulphur ores" and the associated quartzyte, but comparative studies of the iron ores of Minnesota seem to indicate that they are in a formation non-conformable over the lower Laurentian, though when crystallized the resultant gneisses and ores are easily confounded with the older gneisses.

Messrs. Pumpelly, Walcott, Van Hise and Geo. H. Williams in 1890 made a joint reconnoissance of the Adirondacks and while they do not precisely agree in all their results, they are

in accord on the point on which we wish to insist at this place, viz., there is in this region a very important series of modified clastics which are not of Laurentian age, and lie unconformable below the Potsdam sandstone. This series consists of quartzose gneisses, crystalline limestone, graphitic gneisses, and magnetic iron ore. Van Hise says:*

"While the interior structure of the rocks of this series now shows no positive clastic characters, the limestones, graphitic schists, and regularity of what appears to be bedding in the gneisses leave but little doubt that the series was originally clastic and belongs to the Algonkian. The studies of Walcott render it probable that there is here also a basal complex, and along the contact lines of the series Walcott has discovered evidence of an unconformity. This Algonkian is so remarkably like the not far distant original upper Laurentian, in the neighborhood of Ottawa, that one cannot doubt that the two are, or once were, continuous."

In 1892 the writer, accompanied by Dr. U. S. Grant and Mr. Charles Schuchert, made a reconnoissance of the northern portion of the Adirondacks.† We found a gneiss interstratified with marble and quartzyte, some of the gneiss also being very quartzose, the contained free quartz being estimated, in thin section, at 50 per cent., the rest being mainly some feldspar. These were considered to be essentially of the same age, but post-Laurentian, although the existence of the lower, older gneiss was not ascertained. Not only were there fragments of gneiss embraced in the limestone, but isolated lenses of limestone were found embraced in the gneiss. This upper series of gneiss, quartzyte and limestone was parallelized, in the report, with the Taconic series of western New England, not only because of evident lithological differences from the true Laurentian of the northwest, but because of a similarity in order of parts and of general character with the Taconic series on the eastern side of the Adirondacks. We did not, however, ascertain whether the rocks *quartzyte*, *limestone*, *gneiss*, which were found succeeding each other, increased in age from quartzyte to gneiss, or *vice versa*.

In 1893 Mr. F. L. Nason correlated the magnetic iron ores of the Adirondacks and their associated rocks with the iron

*U. S. Geol. Sur., Bull. No. 86, pp. 398, 508, 1892.

†Twenty-first annual report of the Geol. and Nat. Hist. Sur. of Minnesota, pp. 99-112, 1893.

ores of northern New Jersey (AMERICAN GEOLOGIST, vol. XII, p. 25, 1893).

In 1894 J. F. Kemp gave the following ascending order for the rocks on the eastern slopes of the Adirondacks. At the bottom a series of quartz-orthoclase gneiss, sometimes containing hornblende or biotite or augite, with plagioclases; secondly, a series of crystalline limestones closely involved with black schists and gneisses, and lastly a series of intruded rocks of the gabbro family, penetrating both of the others. This order is noticeably similar to the parts of the Canadian Laurentian and upper Laurentian.

It seems from the foregoing that, in respect to the existence of a crystalline terrane, alike in the Taconic and the Adirondack areas, of similar composition and order of stratification, there is a general concord of opinion among those geologists who have paid special attention to the composition of the two areas.

The succession of geologic events in the principal eastern areas may be seen in the following tabulation:

1. Table of geologic features.

ADIRONDACK AREA.	CORTLANDT AREA.	TACONIC AREA.
1. *Potsdam sandstone* Unconformable over (a) Hypersthene rock (b) Crystalline limestone. (c) Schists associated. (d) A quartzyte.		1. Potsdam sandstone unconformable over, (a) Primary, consisting of a changed quartzyte or gneiss (at Whitehall). (b) Olenellus limestone and quartzyte, near Poughkeepsie.*
2. Disruption of No. 3 by hypersthene rock and allied basic eruptives, associated with granite. The former with titanic iron ore and phosphates.	2. Rupturing of the Olenellus limestone and associated schists by gabbro. Metamorphism. Titanic iron ore.	2. Tilting, folding and metamorphism of No. 3.

*Prof. Dwight mentions both these (i. e. Potsdam and Olenellus quartzytes) near Poughkeepsie, but he does not describe their actual contact. (Am. Jour. Sci., (3), XXXI, p. 125.)

3. Quartzyte (gneissic),limestone,schist, succeeding each other (upward?). Specular hematite in the limestone, magnetite in the schists.	3. Cambrian limestone, with schists and quartzyte.	3. Quartzyte, limestone, schist, in ascending order. Ore horizon in the limestone, just above the quartzyte.
4. Older schists, nonconformable below No. 3.		4. Older crystalline rocks, non-conformable below No. 3.

Taking the foregoing in reverse order the great historic and geologic features involved in the table may be recorded as follows:

4. There was, according to available evidence, at least in the Adirondacks and the Taconic area, an Archean complex of schists and gneiss, associated, at least in some parts of Vermont, with greenish and sericitic schists. These constituted portions of the earliest land area or protaxes of the eastern part of the United States.*

3. In the Taconic and Adirondack areas the rocks were formed in crystalline condition prior to the deposition of another series which is now sub-crystalline, or holo-crystalline, and they furnished fragmental materials to this second series. This second series is what has long been known as the Taconic, or later as the Lower Cambrian, and its thickness in Vermont, according to Mr. Walcott, is not less than 15,000 feet. It embraces quartzyte, marble, dark gneisses and soft, often graphitic, schists; and in the limestones, near their base, are often found large and valuable deposits of hematite. These rocks have furnished many new and important data of crystallization, many new mineral species and many problems in petrography. They hold in America nearly all the ore deposits of economic value older than the Lower Silurian.

2. The next step, in the table of events, that marked the age of the Taconic, or Lower Cambrian, was the great irruptive catastrophe which gave origin to the basic gabbros and allied rocks. On all hands it is agreed that this was accompanied by the folding and faulting of the Taconic sediments, by the crystallization of the concerned strata, by the effusive commingling, in some parts at least, of volcanic debris with

*DANA, Bull. Geol. Soc. Am., vol. I, p. 36, 1890.

the ordinary products of sedimentation, and by the formation of surface lavas. These basic rocks, coming from the deeper portions of the earth, are now closely associated with acid eruptives, such as red felsytes and red granites, which may have been generally the products of fusion of the sedimentaries, as recently demonstrated by Bayley in Minnesota.* The metamorphism of the clastic materials of this second series was widespread. It is common to all of the areas represented in the table, but the actual appearance of molten rock among the fragmentals has only been found in the Cortlandt and Adirondack areas. However, in the northern extension of the Adirondack area into Canada this character is well described by Selwyn and Ells.†

1. The last historical event which we can use as a datum for comparison in this connection, is the subsidence of the turbulence and the non-conformable deposition of the Potsdam sandstone (Dicellocephalus zone) in places upon all of the earlier strata, this being accompanied by a progressive subsidence of the region.

It is therefore legitimate, and in accordance with the tendency of the evidence, to infer that the succession of geologic events in the Adirondack region was substantially concordant with that in the Taconic and the Cortlandt areas. The steps were emphasized by the eruptive epochs, and these physical disturbances were probably the main causes of the changes of the Taconic subfaunas. We cannot yet differentiate the eruptives in either of these areas into two or more parts as to dates. We are certain only of one. But in the Lake Superior region, as will be shown, there were at least three separate eruptive epochs.

THE NIPISSING BEACH ON THE NORTH SUPERIOR SHORE.

By F. B. TAYLOR, Fort Wayne, Ind.

When the writer's article on the abandoned shore lines of the south coast of lake Superior‡ was written the position and

*Eruptive and sedimentary rocks on Pigeon point, Minnesota, and their contact phenomena. Bull. No. 109, U. S. Geol. Survey.

†Geological Survey of Canada, Rep. of progress for 1877-78, pp. 5A to 7A; Ditto, 1887-88, Reports on the geology of the eastern townships.

‡AM. GEOLOGIST, vol. XIII, June, 1894.

remarkably even extension of the Nipissing plane to other regions had not been worked out, and some of the phenomena observed had not been correctly interpreted, so that in the paper on the second lake Algonquin* it was necessary to make a few amendments to opinions expressed in the first paper. Although it was desirable in the Algonquin article to bring out the full force of the facts bearing on the extent of the Nipissing beach, it was not possible to do so without adding considerably to a paper already too long. There were no possible outlets for lake Algonquin northward from lake Superior, and the only result of the omission therefore was to leave the attitude of the plane in that direction unsettled.

In the paper on the beaches of lake Superior the probable identity of the Nipissing beach as far as Pie island near Port Arthur was mentioned. But at that time I was unable to recognize it at any point farther north or east. Later, however, when the true character of the Nipissing beach was recognized and its remarkable uniformity over the whole area of observation was perceived, the probability of its extension in the same position to other regions was obvious. It is the object of this paper to show how such an extension is related to the shore lines which have been observed on the north coast of lake Superior.

For the substance of this paper I rely entirely upon the admirable series of observations recorded by Prof. A. C. Lawson in his report entitled "Sketch of the Coastal Topography of the North Side of Lake Superior with Special Reference to the Abandoned Strands of Lake Warren."† Professor Lawson describes strands at forty-eight localities between Duluth and Sault Ste. Marie. I propose to take these up in order and point out those which seem to agree with the peculiar strength and character of the Nipissing beach and which lie in or near the place of the plane of that beach projected from other and better known parts. In this connection it should be remembered that the Nipissing beach is remarkable for the strength of its development. Its drift has suffered extreme reduction by wave action. It generally contains more sand than other beaches and where it is not sandy its pebbles are thoroughly

*Am. Geologist, vol. xv, Feb. and March, 1895.

†Twentieth Annual Rept., Geol. and Nat. Hist. Survey of Minn.

rounded. Its accumulated masses are great in magnitude and its deltas and terraces are of great extent. The notch at the back of its cut terraces is generally deep and the bluff above is often high and comparatively steep and fresh. Sometimes along steep shores of hard rock and along the face of partly submerged cliffs this beach appears to have no distinct representative. But such places do not extend beyond a few miles at most. At some of the best localities I will quote Prof. Lawson's description in full. I take his series by number as published in his report.

Series 1 to 3. Duluth to Hardy's School House. Lower levels above present shore not reported.

Series 4. Two Harbors. The railway station is on a broad plain 35 feet above the lake. We shall see later that this is probably not the Nipissing beach.

Series 5. Beaver Bay. Modern "well defined spit." Also "a bold head presents vertical cliffs over 100 feet high."

Series 6. Baptism River. "Palisades." Vertical cliff for 30 feet with a low beach along its base.

Series 7. Saw-teeth. "Cliff above the present shore" with gently sloping terrace from 84.5 feet above.

Series 8. Carlton Peak. No record below 80 feet.

Series 9 and 10. Poplar River. A low wave-built terrace 6.9 feet. Cut terraces at 12.4 and 21.7 feet. Upper terrace 50 feet wide.

Series 11. Coast east of Poplar River. "Steep sea-cliff rising 14.5 feet from the present shore." Terrace above 150 feet wide and 17.8 feet above the lake at its rear.

Series 12. Good Harbor Bay. Sea-cliff 15 feet high overhangs the present shore. Shingly terrace above this 100 feet wide and 20 feet above the lake at its rear: another terrace 25 feet wide and 27.2 feet high at its rear.

Series 13. Grand Marais. Crests of abandoned beach ridges at 6.1 and 12.1 feet and terraces at 17.5 and 29.1 feet. The upper terrace is 260 feet wide.

Series 14. Kimball's Creek. "From Grand Marais eastward a low terrace, corresponding to * * * the 29.1 feet terrace at Grand Marais, may be observed for several miles along the coast as far as Cow-tongue point." Then at Kimball's Creek there is a flat terrace at 28.5 feet "and above it rises a steeply inclined sea-cliff." "Farther along the shore this terrace is again seen about a mile below Fish-hook point, and again below the mouth of Brulé river."

Series 15. Horseshoe Bay. Three heavy boulder beach ridges at 11.9, 17.6 and 38.6 feet. The front of the last one "is not a simple slope as is the case with the two lower beaches, but its profile shows a distinct step-like feature in its lower part such as may be sometimes seen in the clear water on the subaqueous slope of some of the living beaches of the

lake." Behind the upper beach there is a broad expanse of marshy ground forming a lagoon.

Series 16. Double Bay. From the modern sea-cliff a terrace reaches back a quarter of a mile, at its rear 32 feet above the lake.

The Nipissing plane produced to this coast from the southeast, as shown in the map accompanying the paper on the second lake Algonquin, would strike between 25 and 30 feet above the lake at Grand Marais. This is in very close agreement with the strong continuous beach of 29.1 feet at that place and eastward to a point below Brulé river, a distance of 10 miles or more. Westward from Grand Marais the terrace of 27.2 feet at Good Harbor bay, and that of 17.8 feet east of Poplar river, and that of 21.7 feet at Poplar river, 20 miles west of Grand Marais, are in all probability the same beach. So far as I am able to judge from Prof. Lawson's descriptions, this beach seems to correspond very closely in all respects with the Nipissing beach of the south shore. Its identity as a part of this beach may be fairly assumed for the present. Westward from Poplar river it does not appear to be recognizable, but by calculation the Nipissing beach should pass under the lake about at Beaver Bay, and 25 feet below it at Duluth. The boulder beach ridge of 38.6 feet at Horseshoe bay farther east is undoubtedly the same shore line, its greater hight being due to the fact that it is a beach ridge, while toward the west it is a cut terrace. Measurements of the same shore line often vary seven or eight feet, sometimes more, from this cause. Prof. Lawson's measurements are very precise, even to tenths of a foot. But it is not intended to convey the idea that the former water level can be so accurately determined. It can seldom be made out so closely as not to leave a possible error of at least one to two feet. The wide terrace of 32 feet at Double bay is probably the same beach as that mentioned above, although it is six and a half feet lower. This gives us a stretch of abandoned beach along about 40 miles of the coast and identified with fair probability as the Nipissing beach. The distance from Poplar river to Horseshoe bay on the line of maximum rise for the Nipissing plane is about 25 miles and the rise is from 21.7 feet at Poplar river to 38.6 feet at Horseshoe bay, making a rate of a little more than seven inches per mile, which is about one

than yet has been made that the rise of the Nipissing beach elsewhere. But the rate of rise would be slightly less if allowance were made for difference between the relation of a cut terrace and a boulder beach ridge to the former water level.

The "sea-cliffs" and "palisades" mentioned at the localities southwest of Grand Marais and the spits at Beaver Bay and other places along that shore agree with the supposition of the recent backing up of the water at the west end of the lake. The bases of some of the cliffs, like the Palisades and the Pictured rocks of the south shore, probably stand at the level of a heavy wave-cut below the Nipissing beach and not at that beach itself. The evidence that there was a heavy wave-cut at a lower level before the time of the Champlain uplift has been discussed in the paper on the second lake Algonquin. The next six localities are close together.

Series 17. Grand Portage. From a higher terrace "the ground drops steeply [illegible] to the terrace on which the village is built. This drop represents a sea-cliff which is one of the most striking shore features of Grand Portage. The terrace which extends out from its base is 37.9 feet above the lake."

Series 18. Mount Josephine. "At the base of the hill is a boulder beach, the crest of which is 43 feet above the lake."

Series 19. Wauswaugoning Bay. A beach ridge of coarse red shingle at 43.7 feet.

Series 20. Near Birch Island. Beaches at 17.4 and 21 feet. Nipissing beach apparently not found.

Series 21. Pigeon Point. Beaches at 73.6 and 56.6 feet. Lower levels heavily timbered and not examined.

Series 22. Pigeon River. Terraces at 66.8 and 18.2 feet. Nipissing beach not observed

Series 23. McKellar's Point. Terrace with rear at 48.4 feet and a beach ridge at 36.3 feet. This is about 15 miles northeast of Wauswaugoning bay: and it therefore seems probable that the terrace, and not the beach below, is of Nipissing age.

Series 24. Thompson Island. Beaches at 97 and 28.7 feet. Nipissing beach apparently not observed on the east end of the island. Here and probably at some other places the Nipissing beach may have been removed by a heavy wave-cut at a lower level. At another place on the island a series of caves are developed on the vertical side of a dike. Their floor, taken to be about at the former water level, is 45.6 feet.

Series 25. Shore opposite Flat Island. Broad terrace at 45.3 feet.

Series 26. Above Carp River. No report at low levels.

Series 27. Carp River. "Well defined beach" at 33.8 feet. Above

this "another great beach of perfect form at an elevation of 52.1 feet." Rising immediately from the present shore line there is a rolling succession of small, ill-defined gravel beaches. These indicate "a gradual recession of the water." This is about 13 miles north of McKellar's point, and the upper beach is probably of Nipissing age.

Series 28. Pie Island. "A broad terrace" "abuts against a talus of great angular blocks of trap." Hight 43.5 feet.

Series 29. Brulé Point. Beach at 34.7 feet; not Nipissing. A broad terrace, part of the Kaministiquia delta, extends far inland. At 14 miles its surface is about 55 feet above the lake. It is composed of clay capped with sand. The capping of sand is probably of Nipissing age.* Doubtful whether the beach is of Nipissing age, but the delta may be.

Series 30. Kaministiquia. No report at low levels.

Series 31. Port Arthur. Broad terrace at 61.4 feet. Port Arthur is 10 miles north of Carp river, but it is doubtful whether this terrace is of Nipissing age.

Series 32. McKenzie. No report at low levels.

Series 33. East Side of Thunder Bay. Terrace at 57.5 feet.

Series 34. Back of Thunder Cape. Terrace about 100 feet wide at 49.6 feet.

Series 35. Silver Islet. Between present storm beach and one at 39.3 feet "there are no less than nine distinct well formed shingle beach ridges, rising one above another on a gentle slope." "This portion of the series clearly indicates a gradual recession of the lake, from the stage at which the 39.3 feet beach was built down to the present level."

This is nearly always a safe inference. It is not to be inferred, however, as contrasted with this, that adjacent slopes at the same horizon, but without such beach series, emerge suddenly or haltingly. Such evidence is generally good in a positive sense, but its absence is not equally safe in a negative sense. There is also a terrace here at 59.2 feet. This place is ten miles south of series 33. Still it seems more probable that the upper strand, rather than the lower, is of Nipissing age. From this on to Sault Ste. Marie the points of observation are few and generally far apart.

Series 36. Nipigon. Terraces at 89.8 and 82.2 feet. This place is about 43 miles northeast of series 33. It seems probable that the higher terrace is the Nipissing beach.

Series 37. Mazokama. Terrace at 98 feet.

Series 38. Simpson Island. Broad terrace with steep sea-cliff back of it at 92.7 feet. Well shown by a profile cut.

Series 39. Winston's. No report below a delta at 210 feet.

Series 40. Schreiber. No report below 391 feet.

---

*The lower part of this delta is described on pages 210 and 211 of Prof. Lawson's report.

Series 41. Terrace Bay. Terrace at 96.3 feet.

Series 42. Jackfish Bay. Terraces at 110.1, 102.9, and 84.9 feet. The one at 102.9 feet is described as being prominent and comes closest to the expected place of the Nipissing beach.

Series 43. Three miles east of Jackfish. The railroad follows a terrace which has a maximum hight of 111 feet. "But the precise rear of the terrace is not susceptible of exact determination, and this figure (111 feet) was considered in the field several feet too high for what is probably the true rear of the terrace." This seems to bring this terrace into substantial coincidence with the 102.9 feet terrace at the previous locality. These two are the farthest of Lawson's series towards the north-northeast, which is the direction of maximum rise of the Nipissing plane.

Series 44. Dog River. Terrace at 100.7 feet. This seems a little high, but may be of Nipissing age.

Series 45. Sand River. Terrace at 75.2 feet.

Series 46. Montreal River. Terraces at 78.7 and 61.9 feet.

Series 47. Mamainse. No report at low levels.

Series 48. Sault Ste. Marie. Nipissing beach leveled by Lawson at 49 feet and observed by the writer also on both sides of the river.

Summary and Conclusions.

The rate of rise of the Nipissing plane northeastward from Sault Ste. Marie as measured between there and North Bay, Ontario, is a little higher than from Petoskey to the former place. Carrying this more inclined plane northwestward across the northern part of lake Superior in the direction indicated by the trend of the isobases on the map with the paper on the second lake Algonquin, one is led to expect the Nipissing beach on the extreme north Superior shore at higher altitudes than would be indicated by the production of the plane from its less inclined part on the south shore. The strand which, from Prof. Lawson's description, seems most to resemble the Nipissing beach at the few and scattered places of observation in the extreme north indicates that the Nipissing beach falls somewhat below its expected place as compared with the extended plane of its more highly inclined part. Its altitude in the north appears to be a trifle over 100 feet above lake Superior; whereas, on the Sault Ste. Marie and North Bay plane it should be about 120 to 130 feet. On the south shore plane produced it would be at about 100 feet, and hence it lies more nearly in the latter plane. It appears, therefore, that the hypothetical isobase EE, as shown in the map with the article on the second lake Algonquin, does not

in reality lie parallel with the other lines, but should have been made to curve away toward the north before reaching the meridian of Sault Ste. Marie. The altitude of the supposed Nipissing beach at each place is shown in the following table. The hights are in feet above lake Superior, which is 602 feet above sea level. In the fourth column the approximate theoretical hight of the Nipissing beach is given for each place as measured on the Nipissing plane produced from the south shore. The letter *t* stands for terrace; *r* for beach ridge; *br* for boulder beach ridge; *c* for cave; and *d* for delta.

Series.	Form.	Observed Hight.	Theoretical Hight.	Series.	Form.	Observed Hight.	Theoretical Hight.
9, 10	t	21.7	20	29	d	ap'r.55 ?	60
11	t	17.8	21	31	t	61.4	63
12	t	27.2	26	33	t	57.5?	70
13	t	29.1	28	34	t	49.6?	65
14	t	28.5	31	35	t	59.2	66
15	br	38.6	35	36	t	89.8	95
16	t	32	37	37	t	98	96
17	t	37.9	41	38	t	92.7	93
18	br	43	42	41	t	96.3	97
19	r	43.7	43	42	t	102.9	100
23	t	48.4	50	43	t	111 ?	90
24	c	45.6	55	44	t	100.7?	91
25	t	45.3	56	45	t	75.2	78
27	r	52.1	58	46	t	61.9	72
28	t	43.5?	58	48	t	49	

Out of this total of thirty places it seems probable that the Nipissing beach is fairly well identified in all but six, and it is possible that those also are of Nipissing age. It seems probable, therefore, that the identity of the beach is made out at half or more of Lawson's forty-eight places of observation. The greatest number of departures from close coincidence appear to be in the region of Thunder bay. Where cutting by wave action is very active it is not uncommon for a cut at a lower level to remove the remains of a higher beach. On that account some of the terraces which seem a little low have been taken as possible representatives of the Nipissing beach.

On the south shore there is evidence that lake Superior was not affected by eastward elevation until after it had become independent in consequence of a very gradual and even north-

ward elevation.* The Nipissing beach declines westward from an altitude of 50 feet at Sault Ste. Marie to 25 feet below the present lake level at Duluth. But if the lake became independent before the eastward uplift began, then at that time its level was 75 feet lower than now at Duluth; for the last or lowest beach of the independent lake before the eastward uplift was formed about 50 feet below the Nipissing beach at Sault Ste. Marie. I have called this the Sault beach. One of the pretty questions which this study suggests is the possible identity of this beach on the north shore. If differential northward elevation went on within the Superior basin after independence and before the eastward uplift, this beach would be found more than 50 feet below the Nipissing beach on the north shore. Along that part where the Nipissing beach is more than 70 or 80 feet above the lake, we might therefore expect to find the Sault beach, provided it was strongly developed. An examination of Prof. Lawson's descriptions with reference to this subject shows the presence of a beach which may ultimately prove to be the one referred to. It is at least tolerably persistent and lies about 60 feet below the Nipissing beach. At series 36 and 38 its altitudes are 28.4 and 33.7 feet respectively, and at series 42, 43 and 44 its hight is 33.5, 40 and 39.7 feet respectively. These localities are nearly in a straight line parallel with the isobases. The identity of this beach is of course uncertain on this showing alone, but the suggestion may be worthy of future consideration.

Professor Lawson concluded that there is little or no deformation of the lower shore lines. His conclusion, however, depended upon two things: first, on the fact that his tracing was not continuous; and second, on his method of correlation, in which he assumed horizontality on insufficient evidence. His descriptions, however, are so clear and detailed that I believe the Nipissing beach is traceable by them with a fair degree of certainty.

In one of his recent papers Mr. Upham says that he finds reasons which "justify to a remarkable degree Dr. Lawson's opinion that the ancient shore lines of lake Warren in the

*This point is fully discussed in the paper on the second lake Algonquin referred to above.

Superior basin remain parallel with the water level of to-day."* Mr. Upham's belief appears to be based upon correlations made partly by Prof. Lawson and partly by himself. But in neither case, as it seems to me, is there safe ground for such correlations. In order that Prof. Lawson's classification of the strands in horizontal series might be true and valid as applied to the lower shore lines, the fact of horizontality should first have been ascertained by substantially continuous tracing of some strongly formed, persistent strand, like the Nipissing beach. In his table of strands the maximum discrepance from horizontality is about 13 feet. In general, then, if the strands vary more than this amount from horizontality anywhere in the whole Superior basin—if they rise or fall more than this from Duluth to Sault Ste. Marie or from Marquette to Jackfish bay—the significance of the table as a true classification is destroyed. The method itself is one which cannot be safely used without a thorough fore-knowledge of the exact position of the strands; and even then, if they are not horizontal, it is useless. If the correlations pointed out in this paper are true, then the Nipissing beach rises somewhat more than 80 feet from Poplar river to Jackfish bay, and crosses seven of Prof. Lawson's strands; from Duluth it rises about 125 feet, and crosses about a dozen strands. This, to be sure, is a small amount of inclination as compared with that of some beaches at other places. But it lacks a good deal of being "parallel with the water level of to-day."

Dr. A. C. Lane, of the Michigan Geological Survey, also reports deserted beaches on Isle Royale and on Keweenaw point, which agree in a general way with the results of the writer.

If the Nipissing beach has been truly made out from Prof. Lawson's observations, it adds largely to the known area of very recent terrestrial deformation. The basin of lake Superior bears about the same relation to James bay at the south end of Hudson bay that lake Erie does to the lower St. Lawrence valley. The distance between their eastward shores is

*Am. Jour. Sci., III, vol. XLIX, Jan., 1895, p. 7. Mr. Upham's detailed correlations of the shore lines around lake Superior, and north of lake Huron and Georgian bay to lake Nipissing, are given in the Twenty-second Annual Report, Minn. Geol. Survey, for 1893, pp. 57 65; and in Bulletin Geol. Soc. Am., vol. VI, pp. 21-27. Nov., 1894. He regards the shore lines as now considerably inclined, but less for the Nipissing plane than is indicated in this paper.

about 300 miles, which is about the same as the distance from Buffalo to Montreal, and it is in the same direction. Dr. Bell reports Pleistocene marine shells in stratified deposits overlying the drift up to more than 500 feet above the sea on the shores of Hudson bay, and on the Kenogami river up to within 150 miles of lake Superior. There is much reason to believe that the Hudson bay region, as well as the St. Lawrence valley and the Great lakes, was involved in the Champlain uplift.

This attempt to identify the Nipissing beach in Prof. Lawson's work is not offered as final or conclusive. But it is believed that it is the best that can be done in the present state of our knowledge of the north coast of lake Superior.

A HYPSOMETRIC MAP OF MISSOURI.

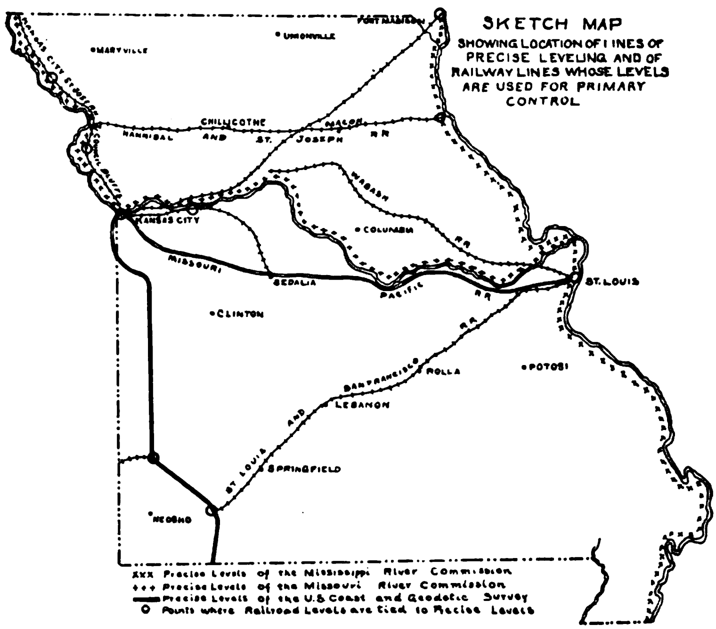
By C. R. KEYES, Jefferson City, Mo.

The elevations of the various points within the boundaries of Missouri are, as in the case of most other states of the Union, known only in a somewhat general way. The published information of this character by the different states is meager and is often restricted to a few scattered lists of railroad elevations unrevised and usually started from some point other than sea level as a datum. The importance of having the zones of equal altitude more than approximately determined and the convenience of having all elevations referable directly to mean tide as a datum line is fully appreciated by all who have had areal geological work to do. Its fundamental necessity is recognized whenever detailed topographical mapping immediately precedes or accompanies the tracing and investigation of the various rock formations. In the majority of the states no careful topographical mapping has been undertaken under the official direction of their respective geological surveys. Most of the more exact relief work of this character which has been accomplished in this country has been under Federal auspices, though some of the states have carried on similar mapping but in co-operation with the topographical organization of the general government. Usually, then, when the elevations of the different parts of any district are con-

sidered railroad levels are depended upon almost entirely to give starting points for subsequent determination of altitudes by barometrical means. Unless carefully checked, however, railroad levels are sufficiently inaccurate to render untrustworthy all attempts to establish a reliable datum for detailed mapping and to give rise to very erroneous results in the calculations involving the elevations of particular places. Thus, figures from this source which are liable to vary several feet in either direction usually interfere seriously with accurate work and in many cases practically make negatory the results sought, as may be subsequently shown by lines of level more carefully run.

This was the condition of things which confronted the Missouri Geological Survey at the beginning of its work of detailed topographic mapping. To relieve this uncertainty in regard to the starting points, the profiles of the railroads traversing the state and the lists of elevations of all stations on them were collected. Within the past year the recalculation of all points, their adjustment to more accurate datum lines, and their reduction to mean tide level has been finished. An essential aid to this work has been the various lines of precise levels which have been run under Federal auspices. Missouri has been especially favored in this respect. The Mississippi River Commission has established a line along the entire eastern border of the state. This is part of the series started from Biloxi on the Gulf of Mexico and carried up the Mississippi river. The Missouri River Commission has taken up the work from the mouth of the Missouri starting with a bench mark of the organization just mentioned and has carried it across the state to Kansas City and from thence northward along the western boundary, to beyond the Iowa line. The U. S. Coast and Geodetic Survey has also run a line of levels, as a part of its transcontinental work, along the Missouri Pacific railway from St. Louis to Kansas City, and also from the latter point southward near the western boundary into Arkansas. Where the lines of railway intersect those of the precise levels there is afforded an accurate basis of the correcting of any errors which may exist in the former. In the accompanying sketch map of Missouri there are shown the lines of precise levels which cross the state and the principal

lines of railway which have been utilized in controlling the elevation of the other roads. The lines of precise levels, therefore, form the primary base lines, and the railway levels the secondary base lines. The latter form a complicated plexus or network of level lines upon which all mapping may be based. There are more than 6,500 miles of railroad in Missouri and more than 200 intersections, so that comparisons could be readily made at short intervals in order to bring out



any discrepancies which existed. As has been stated, this has now been done. In some instances differences of nearly 50 feet have been found in the previously determined elevations.

With the completion of the revision of the altitudes of the state the foundation has been laid for detailed mapping both topographic and geologic for all Missouri. Any future changes in the recently determined figures which may be found necessary may be depended upon as being so small in value and as affecting the present results so slightly, that they may be practically neglected. In mapping which may be done before such minor corrections or adjustments are brought to light no essential changes in the cartography

are made imperative, and future revisional work in this direction is reduced to a minimum. With the exception, perhaps, of a few limited districts in the south central portion of the state, every county in Missouri will have a number of accurately determined points from which detailed mapping may proceed, and all elevations may refer directly to mean tide level.

CENTRAL IOWA SECTION OF THE MISSISSIPPIAN SERIES.*

By H. Foster Bain, Des Moines, Ia.

Throughout the broad Mississippi valley there is a series of beds, in the main calcareous and largely made up of heavy bedded limestones, which lie between the Coal Measures and the Devonian. These rocks have been extensively known and studied under the names "Subcarboniferous" and "Lower Carboniferous" and to them H. S. Williams has applied the name Mississippian series, a modification of a term first proposed by Alexander Winchell. They are typically developed in southeastern Iowa and the adjoining regions and have been most studied along the Mississippi river. They form, however, in the main a definite, easily recognized stratigraphic unit throughout the Mississippi valley. This term has been recently extended to cover a similar calcareous series occupying an infra-basal position relative to the Coal Measures of the Appalachian province† and has thus lost its original geographic significance.

The upper delimitation of the series is throughout Iowa a matter of small difficulty as it is separated from the succeeding beds of the Coal Measures by a marked unconformity of erosion. The lower limit is not, however, so easily recognized and around the question of its delimitation considerable controversy has in times past arisen. Up to the present time the chief studies on the series as developed in Iowa have been carried on along the Mississippi river, and from the exposures there a general section has been constructed which may be called the southeastern Iowa section. During the two past

*Published by permission of the State Geologist of Iowa.

†Campbell, M.: Bul. U. S. Geol. Surv., No. 111, p. 37, 1893.

field seasons similar exposures along the streams of Mahaska, Keokuk and Washington counties have been studied and thus an independent general section, which may be called the central Iowa section, has been constructed. At the present these two sections have not been connected by detailed stratigraphic work though the continuity of the major divisions has been traced.

FORMATION.	BEDS.	EXPOSURES.
Saint Louis.	Pella. Verdi. Springvale.	Marion county. Washington county. Keokuk county.
Augusta.		Keokuk and Washington counties.
Kinderhook.	Wassonville limestone. English River grits. Maple Mill shale.	Washington county. " " " "

SAINT LOUIS FORMATION.

Pella beds.—These beds are typically developed in Marion county, but also occur in all three of the other counties mentioned. They represent the quiet settled conditions of open sea deposition and mark the period when the shore line had probably reached its maximum northern position. The beds consist largely of thin shelly limestone with the interstices filled with a calcareous marly deposit crowded with fossils. The limestones are also fossiliferous but the major portion of the forms occur in these marly layers. At the Klein quarry near Pella a portion of the beds is well exposed and the following section may be seen:

		Feet.
8.	Drift	12
7.	Clay marls with brachiopods	2
6.	Clay marl "coral layer"	2
5.	Clay with brachiopods	4
4.	Clay shale, "Spirifer layer"	1
3.	Limestone	2
2.	Clay shale, "Rhynchonella layer"	1
1.	Limestone	5

The limestones at times become more heavily bedded and occasionally occur in considerable thickness. Along the Des Moines river in Marion and Mahaska counties they attain a maximum thickness of probably seventy-five feet.

This phase of the Saint Louis is the one generally present in Marion county; it is frequent in Mahaska and not unusual in Keokuk county, being seen in the small quarries east of What Cheer, similar openings near Sigourney, and occasionally along the Skunk river. In Washington county the succeeding erosion has very generally cut it away, though at Brighton it is typically preserved.

The greater portion of the fossils which are labeled as Saint Louis and as coming from this region are from these layers. The fauna is more abundant perhaps in number of individuals than of species though the latter are not few. It is very largely made up of brachiopods and other open sea forms and includes among many others the following species: *Spirifer littoni* Swallow, *Athyris subquadrata* Hall, *Productus marginocinctus* Prout, *Pentremites koninckiana* Hall, and *Zaphrentis pellaensis* Worthen.

Detailed paleontologic work has not yet been done in any of the region.

Verdi beds.—Preceding the quiet waters in which the Pella beds were laid down there was a period in which apparently there were many and rapid changes. This period is marked by a series of rapidly alternating sandstones and limestones. These individual layers are rarely of more than very local extent and have no stratigraphic value. The sandstones are in part fine-grained, white, calcareous, and in part coarse and ferruginous. The limestones are compact, fine-grained, ash gray in color and break with a clear conchoidal fracture. They are very rarely fossiliferous. Frequently they become brecciated, and it is this particular phase which once gave name to the entire formation. The breccia consists usually of small, roughly angular blocks of limestone from one-half to two and one-half inches in diameter, cemented by a calcareous cement. In weathering, the differences between the brecciated blocks and the matrix are made very apparent. The brecciation is in places very fine and seems to grade into a true oölitic structure, such as is characteristic of the Bedford stone of Indiana. Again the brecciation may become of a very coarse type and the calcareous matrix be replaced by loose or partially consolidated sands.

In the old railroad quarry near Verdi station in Washing-

ton county this latter phase is admirably shown. Here huge blocks and slabs of limestone, four feet long and six inches or more thick, are seen lying at all angles, apparently just as they fell from an overhanging cliff and were buried in the loose sands at its base. The sandy portion of this bed frequently becomes of considerable thickness, thirty feet or more, and is heavily cross-bedded. It might at times be readily confused with the basal portion of the Coal Measures except for the fact that careful search usually reveals at some point a layer of the characteristic compact limestone of the Saint Louis interbedded with it.

In the old railroad quarry near Atwood, in Keokuk county, the limestones and sandstones are fairly regularly interbedded. This seems to mark the closing portion of the Verdi deposits, the transition from them to the Pella being nowhere marked by a sharp physical break. The signs of disturbance, so abundant in the one, give place to the marks of greater quietude in the other. The sands and broken blocks of the shore are replaced by the limestones and marls of the open sea.

Springvale beds.—Below the beds just described is a thin but very constant bed which has been recognized along the Skunk river in Washington and Keokuk counties. It is made up of a blue, somewhat calcareous shale, which weathers readily into a soft earthy brown mass. It is in places arenaceous and is usually known locally as a sandstone. It has a fairly uniform thickness of twenty to twenty-five feet and is very rarely fossiliferous. It is well exposed at the old Springvale mill south of Delta in Keokuk county and shows here the blue shaly character as well as the weathered brown aspect. Good exposures also occur on Crooked creek south of Washington. The only fossils so far found in this bed are a few obscure forms which occur at Brighton. These are imperfectly preserved and are in the main of only slight value for purposes of correlation. On the whole, however, they are such forms as might readily be found in either the Keokuk or Saint Louis. Stratigraphically the beds present closer relations with the overlying Saint Louis than with the underlying Augusta and for the present the Springvale is placed in the Saint Louis.

In southeastern Iowa Gordon,* in studying the Saint Louis, has found it to be divided into three members:

(1) Gray, compact and granular limestone.
(2) Brecciated limestone.
(3) Arenaceo-magnesian limestone beds.

These three divisions correspond well with the beds of central Iowa and, while the two sections have not as yet been definitely correlated by detailed stratigraphic work, there can be little doubt of their equivalency.

AUGUSTA FORMATION.

The rocks now grouped under this name were long known and studied in southeastern Iowa and neighboring regions under the names Keokuk and Burlington limestones. Recently it has been shown that these two are in reality one formation both stratigraphically and paleontologically. It is interesting to note that this is in strict accord with the facts as observed in central Iowa. Indeed, if the work on these rocks had begun here rather than in their type locality it is doubtful if the formation would ever have been divided. The lithological and faunal characteristics of the different exposures throughout Washington and Keokuk counties are almost identical. There is throughout the same coarsely sub-crystalline dark gray or drab to white limestone, showing streaks oxidized brown; the same irregular layers of chert; the same clay partings and other features of identity. This is not due to the fact that only a portion of the formation is exposed, for the outcrops show the entire thickness from the base of the Saint Louis to the top of the Kinderhook. There is throughout a considerable uniformity of material. The arenaceous layers which appear in Louisa county seem to be entirely absent. Everywhere there are indications of stable conditions and a corresponding uniformity of faunal features is noticed. Only occasionally is a form usually considered as distinctively Keokuk, such as *Spirifer logani* Hall, or as characteristically Burlington as *Spirifer grimesi* Hall, found. The larger number of fossils found might be labeled indiscriminately from any one of the exposures.

In Washington county this formation underlies a broad belt running through the central part of the county. The princi-

*Geol. of Van Buren county, not yet published.

pal exposures are found on Crooked creek, Davis creek, and on English river. In Keokuk county the best exposures occur on the Skunk river where the rock is brought above the water level by a series of small anticlines.

KINDERHOOK.

The rocks which may be considered as belonging to this formation, as at present defined, are exposed principally in Des Moines, Louisa and Washington counties. It is the exposures in the latter county which have been particularly studied. The outcrops occur along Davis and Goose creeks and up English river to a mile or more beyond Wassonville. Three well marked divisions are found: the Wassonville limestone, English River gritstones and Maple Mill shales.

Wassonville limestone.—This is an earthy magnesian limestone, in places becoming arenaceous. It is fossiliferous and is traversed by chert bands, which are also full of fossils. As exposed at the old Wassonville mill and in that neighborhood, it attains a thickness of about thirty-five feet. It is not always sharply separated from the bed below.

English River gritstones.—At a number of points from Kalona to Wassonville this bed is seen just below the Wassonville limestone. It is a fine-grained, buff to white sandstone, or gritstone, to use Worthen's name, and is exceedingly fossiliferous, the forms being preserved as casts. The fauna presents a general agreement with the "yellow sand layer" at Burlington. The relations between the gritstone and the limestone are intimate.

The gritstone is usually sharply divided from the underlying shale, as at Maple Mill, where a two-inch band of non-fossiliferous limestone separates them. Near Kalona, however, they are interbedded. It has a maximum thickness of about twenty feet near Maple Mill, but farther east feathers out and disappears. At the Riverside mill the limestone rests directly upon the shale.

Maple Mill shale.—The lowest member of the central Iowa Kinderhook is a non-fossiliferous, dark green to blue argillaceous shale, which is exposed at a number of points on English river. It has a maximum exposure of less than thirty feet, but is known to be considerably thicker. Probably 200 feet i[illegible] correct thickness. The Kinderhook of south-

eastern Iowa is typically exposed at Burlington, where the layers referred to the formation are:*

		Feet.
6.	Rather soft, buff limestone; probably somewhat magnesian, apparently sandy locally	5
5.	Gray oölite	4
4.	Soft, fine-grained, yellow sandstone, highly fossiliferous	6
3.	Gray, impure limestone, fragmentary, often with an oölitic band below	9-13
2.	Soft, fine-grained bluish or yellowish clayey sandstone, passing into sandy shales in places	20-30
1.	Blue clay shales, fossiliferous, exposed above water	50

The Maple Mill shales may be correlated with number one of this section. The English River gritstones contain a fauna presenting affinities to that of number four, which is the "yellow sand" from which the principal collections of Kinderhook fossils have, in Iowa, been made. Worthen† considered the beds which we have called the Wassonville limestone as the equivalent of the oölitic layer, number five.

The Choteau limestone of Missouri may be represented in numbers four and five of the Burlington section. The remainder of that section is probably the equivalent of the Hannibal shales. The lowest member of the Kinderhook, the Louisiana limestone, is not represented at the surface in Iowa, if indeed, it be present at all.

The rocks now referred to as Kinderhook were first studied in Iowa by Owen and were by him and his immediate successors considered to be Carboniferous. Later they were considered by Hall and his fellow workers to be Devonian and were correlated with the Chemung of New York. In 1861 Meek and Worthen‡ recognized their Carboniferous affinities and proposed the name Kinderhook for all the strata between the base of the Burlington and the Black slate, quite generally recognized throughout the upper Mississippi valley. The upper line of delimitation is not difficult to recognize in Iowa, but owing to the absence of the "black slate" the lower limits are not so clearly defined.

The line of juncture between the Devonian and the Kinderhook is nowhere exposed in this state. While the exact divis-

*Keyes: Bul. Geol. Soc. Am., III, 285, 1892.

†Geol. of Iowa, vol. I, p. 236, 1858.

‡Am. Jour. Sci., (2), XXXII, 228, 1861.

ions of the Devonian have not as yet been definitely worked out, it is known that a well marked Devonian fauna, that of the Lime Creek shales described by Calvin,* probably represents the closing stages of that period. It has recently been suggested that there is reason to believe that the Louisiana limestone, the basal member of the Missouri Kinderhook, may be of Devonian age.† As has been said, there is little reason to believe that this formation is present in Iowa, and the lowest member here is probably to be correlated with the Hamilton shale.

The larger collections of fossils from the Iowa Kinderhook have come from the sandy layer below the oölite at Burlington. In 1885 Tiffany‡ maintained, and quoted H. S. Williams as authority, for the statement that this bed was Devonian.

Until recently the shales lying at the base of the Burlington section have been regarded as non-fossiliferous. A number of fossils have, however, now been collected from them. These include a few *Spirifers, Rhynchonellas and Lingulas*, species undetermined, which are non-diagnostic. There are also certain obscure crustacean forms. In addition to these there is one specimen which may be referred to *Gomphoceras*, sp. und. The bearing of this form is important. The genus has been regarded as terminating with the close of the Devonian. The only exception has been *Gomphoceras potens* Hall, described from the Waverly. The author states that the most important structural parts of this specimen were missing, a statement which the figure given amply justifies. For the present *Gomphoceras potens* can hardly be considered to be more than a doubtful species. There are also a few specimens of an *Orthis* very closely allied to *Orthis iowensis* Hall, and differing from it only in some features of the muscular scar. The differences are not great, and yet a species maker might regard the form as new. In general, however, it very closely resembles the typical forms from the Lime Creek shale. *Gyroceras Burlingtonensis* Owen, is also found, it being a form originally described from the oölitic bed of the same locality. The genus *Gyroceras* presents closer affinities with the under-

*Bul. U. S. Geog. and Geol. Surv., [illegible], 1878.

†Keyes, Am. Geologist, x, 380-384, 1892.

‡Geol. of Scott county, Iowa, and Rock Island county, Ill., etc., p. 28. Glass and Hoover, Davenport, 1885.

lying Devonian than the higher Carboniferous, only five out of the forty species now referred to the genus being found above the Devonian. In each case these species are described from the Kinderhook or the Waverly beds.

It will thus be seen that so far as the paleontologic evidence goes the shale shows Devonian affinities. This shale, as exposed at Burlington, may be traced almost continuously northward to the mouth of English river, and up that stream connecting with the Maple Mill shale.

It seems not improbable that ultimately, in Iowa at least, a considerable portion of the beds now referred to the Kinderhook, including this shale, may be found to have closer affinities with the Devonian than with the Carboniferous.

EDITORIAL COMMENT.

THE SHAW MASTODONS.

An exceedingly interesting addition has been recently made to the already valuable collection of the Cincinnati Society of Natural History. In June, 1894, a cistern was excavated on the land of Miss Louise Shaw, and some fragments of bone were thrown out. With unusual but highly commendable appreciation of the find, Miss Shaw immediately communicated the news to the society and suspended operations on the cistern for a month or more until arrangements were made to examine the place. Mr. Seth Hayes, the director of the museum, superintended the work of excavation, and after three weeks of constant and careful labor extricated from the clay the often fragile specimens which now adorn the society's rooms in Cincinnati. These prove the presence of at least three individuals, two of which present the character, thus far unknown in America, of *two* well developed but small tusks in the *lower* jaw. Occasionally a single small incisor (tusk) is found in the lower jaw of the American mastodon (*M. americanus*), but the species showing two of these organs have hitherto been limited to the old world. It is noteworthy also that the double lower tusks characterize the older forms of the mastodon, such as *M. angustidens* of the Miocene, and

from this a more or less distinct transition can be traced to the last of the series in the Pleistocene or perhaps even the post-Pleistocene (Human) period.

The remains were found in a bed of blue clay about seven feet thick and extended from bottom to top, and even in one case protruded below into a gravel and above into a yellow clay. The age of this still remains in doubt. A few recent fresh water shells of small size were found in sand-pockets in the clay, but their evidence is not sufficient to decide the question. Dr. Edward Orton is "of the opinion that the mastodon remains are of post-Glacial age," and possibly, in the absence of conclusive testimony, this is the safest position. But from the paleontological side comes a strong suggestion of greater antiquity which further evidence may confirm. E. W. C.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

The Penokee Iron-bearing series of Michigan and Wisconsin. By ROLAND DUER IRVING and CHARLES RICHARD VAN HISE. (Monograph XIX, U. S. Geol. Survey, Washington, 1892. Published 1894.) This long-advertised volume appeared from the Government printing office in the latter half of 1894. The death of Prof. Irving in May, 1888, deranged the plans and the work and devolved the chief responsibility upon Prof. Van Hise. The latter was formerly a student of Irving, and well understood Irving's purposes as well as his geological ideas, and he has mirrored them faithfully, there being but slight departure from the well-known views which Irving entertained on the geology of the Penokee series. For instance, in the matter of the taxonomy and the geographical distribution of the formations of the Lake Superior region as exhibited in plate I of this work, they are the same as exhibited in plate XXII of the Fifth annual report of the U. S. Geol. Survey (1883-84) prepared by Irving eleven years earlier to accompany his "Preliminary paper on the investigation of the Archean formations." There is a slight change in the extension of the Mesabi iron range to the Mississippi river, and in the spur of the iron-bearing series which runs northwestward from Marquette, and the term Algonkian is fully introduced. Irving proposed Eparchean or Agnotozoic, but the vote of the geologists of the survey determined in favor of the term Algonkian. On this plate, therefore, everything that was before called Huronian by any one is still called Huronian, but this term and these areas are united with Keweenawan and Keweenawan areas under the single designation Algon-

kian. The introduction of a new name, with the uncertain upward and downward limitations which are said to bound the application of this, is unfortunate for American geology, for while adding nothing to the definiteness of other terms, its own existence is founded on uncertainties both at the top and at the bottom. To assign a terrane to the "Algonkian" is worse than to assign it to the Huronian. The latter term is beginning to acquire some delimitation. It is now known to embrace two great formations, and originally embraced three. These three are now covered by the new term, but the new term goes lower, inasmuch as it descends to the lowest recognizable sediments. It extends from the base of the Cambrian, wherever that may be, to the horizon of the lowest recognizable sediments.

There are two topics discussed in this work to which it would be well to call attention: 1st, the cherty carbonate, and 2d, the origin of the ores.

The cherty carbonate has played a very important and rather curious role in the literature of the Penokee region. From being considered the basal member of the Huronian (i. e. the true Huronian according to Irving, the upper Huronian of Van Hise,) and the source of the iron ores of the region by a process of chemical change and concentration, it is now removed from the Upper Huronian and put into the Lower Huronian, constituting there its sole representative,and is relieved from its responsibility for the origination of the iron ore. The facts on which Van Hise now puts this in the Lower Huronian were known by Irving, but he did not consider them as sufficient to warrant the interposition of so profound a break above the limestone as this volume expresses. The fact that the strike of the limestone is identical with that of the iron-bearing and the quartz-slate members points to the essential concordance of the limestone with the Upper Huronian. It is, to say the least, a rather singular member of the Penokee series. It is wanting in places on the north side of lake Superior in the same manner. indeed it is hardly known in Minnesota, but reaches a large development about Thunder bay.

As to the origin of the iron ore of the Penokee range, it is in the first instance found in a "cherty iron carbonate," separated by several hundred feet from the foregoing "cherty carbonate." From this condition the rock passes by chemical transformations to ferruginous slates and cherts and to actinolitic and magnetitic slates, the ores themselves being secondary concentrations found at the lowest horizons. Mr. J. E. Spurr, when examining the equivalent ores of the Mesabi iron range for the Minnesota Geological Survey, after careful microscopic researches, reached the conclusion* that the cherty iron carbonate is itself a secondary rock, and that the real source of the ore is in a glauconitic sand which, being in unstable chemical condition, gave origin both to calcite and to hematite. This rock, in its original condition, is greenish, but easily becomes red, or reddish. It then appears to consist of amorphous silica in which float blood-red globules. The globules are some-

*Bulletin X of the Minnesota Survey.

times nearly black, or partly white. It is the rock which in Minnesota has been named taconyte, and is illustrated by several plates, in microscopic section both by Spurr and by Van Hise. It seems to be a kind of jasper characteristic of this geological horizon. Mr. Spurr is inclined to believe the glauconite is of foraminiferal origin. N. H. W.

Meteoritenkunde von E. COHEN. *Heft 1. Untersuchungsmethoden und Charakteristik der Gemengtheile, mit 39 Figuren.* (Stuttgart, E. Schweitzerbart'sche Verlagshandlung [E. Kock]. Pp. xiii, 340, octavo. 1894.) This volume is only the first of several which have been planned by the author, and if they shall all be finally completed he will have reviewed every phase of the subject of meteorites. This part is devoted to methods of examination and the composition of meteorites. It contains a short historical sketch of the chemical results attained by simple chemical analysis by Howard in 1802. After Howard's researches there followed a large number of analyses of other meteorites, performed by Fourcroy, John, Klaproth, Langier, Proust, Stromeyer, Thenard, and Vanquelin. These resulted, between 1803 and 1834, not only in verifying the discoveries of Howard which had shown a similarity of nature and therefore a similarity of origin, but also in the detection of manganese, chromium, carbon, chlorine, calcium, aluminum, sodium, cobalt, potassium and copper. Berzelius added tin in 1834. The author gives an interesting sketch of the methods and discoveries of later chemical investigators down to 1891.

A similar sketch is given of the progress of the determination of the minerals of meteorites, by chemical and petrographic methods. Each element and each mineral then has its special exposition, in the course of which everything that is known of their manner of occurrence and their pecuiarities and combinations, is fully detailed, with copious references to literature. Throughout the author has added much original matter.

The work is a thorough compend of the known meteorites of the world, and at the same time it is much more than a compilation, in that the author has discriminated and condensed, or has criticised and enlarged the work of his predecessors by his own investigations.

N. H. W.

Geotektonische Probleme, von A. ROTHPLETZ. (107 figs., 10 plates, pp. 175, E. Koch, Stuttgart, 1894.) This volume is devoted to the faulting and folding of the rocks of the earth's crust, with illustrations taken from the best authorities. In respect to North America the author has employed the generalized sections of Rogers for the Appalachians and of McConnell for the Rocky mountains. The special contributions of Willis (Thirteenth report, U. S. G. S.), of Dana in western New England, of C. W. Hayes in Alabama and Georgia, of Hobbs in the Housatonic valley and of Prof. Safford in Tennessee are brought into the general review, and some are illustrated. N. H. W.

Ofversigt af Kongl. Vetenskaps-Akademicus Forhandlingar 1894. No. 10. Stockholm. Dr. G. Lindström reports the discovery of a Silurian fish

(gen. *Cyathaspis*) on the southeast coast of Gotland in the Baltic sea. It is from the oldest beds of clay slate in Gotland, equivalent to the Wenlock and thus older than the pteraspidian fishes of the Baltic provinces of Russia, or those found in Galicia. He considers Pander's conodonts of the Russian Cambrian greensand are not fish-remains, and he thinks that the fish-remains from North America referred to the Lower Silurian are not so old, because they are quite Devonian in type. G. F. M.

A Preliminary Report on the Marbles of Georgia. By S. W. McCALLIE. (Geol. Sur. of Ga., Bull. No. 1, 92 pp., 14 pls., 2 maps; 1894.) This is the first report which has been issued since State Geologist Yeates has had charge of the survey. The marble beds occur in the belt of crystalline rocks which crosses the northern part of the state. Descriptions of the various quarries and exposures are given in some detail. The report is devoted almost entirely to the economic aspects of the subject, and comparatively little is stated concerning the geology of the region in which the marble occurs. U. S. G.

Geological Survey of New Jersey, Annual Report for 1893. By JOHN C. SMOCK, State Geologist. 457 pages; 5 maps; 10 plates; and 28 figures in the text. (Trenton, 1894.) After the administrative report of the state geologist, comprising 29 pages, this volume contains a report on the surface geology, by Prof. R. D. SALISBURY, nearly 300 pages; on the Cretaceous and Tertiary geology, by Prof. W. B. CLARK, 25 pages; on the structure of the Archean rocks in the vicinity of Hibernia, N. J., and their relation to the ore deposits, by J. E. WOLFF, 11 pages; on water-supply and water-power, by C. C. VERMEULE, 13 pages; on artesian wells in southern New Jersey, by LEWIS WOOLMAN, 33 pages; and on the minerals of the state, with notes of mineral localities, 20 pages.

An abstract of the first section of Prof. Salisbury's report, treating of the Yellow Gravel series, has been given in the last March AM. GEOLOGIST (pp. 203, 204). The second section treats of the extra-morainic drift, and is accompanied by a map, which, with the text descriptions, admirably displays the evidence of extensive erosion and a long time interval between the oldest deposits of drift and the moraine which lies somewhat farther north upon or near the margin of the newer drift. This moraine is more exactly mapped and described than in previous reports. Another section describes kame terraces, laid down in valleys that were still partly occupied by the departing ice. The glacial striæ and drift of the Palisade ridge, which rises steeply on the west side of the Hudson river north of New York and Jersey City, are of special interest in showing that a general current of the ice-sheet passed from northwest to southeast across the highland.

A very thorough exploration, chiefly by Mr. H. B. KUMMEL, of the shores, deltas, and other proofs of the ice-dammed lake Passaic, is elaborately reported, with a special map. The lake area extends about 30 miles from southwest to northeast. Its old shore-lines have an ascent of 25 feet in the first six to ten miles from the southern end; in the next ten miles there is an ascent of 15 feet; and in the last ten miles

northward, again an ascent of about 25 feet. The average differential uplift of the land, since the time of the lake existence and the closing part of the Ice age, is thus about two feet per mile, being intermediate in amount between that of the southern half of lake Agassiz and that of the east end of lake Iroquois. The maximum width of lake Passaic was about ten miles, and its maximum depth was about 225 feet.

W. U.

CORRESPONDENCE.

Divisions of the Ice Age in the United States and Canada. After reading Mr. Upham's papers in the last December and March issues of the *American Naturalist*, I have been led to reflect further upon the succession of the glacial deposits in North America, and to send in this letter informally some of my conclusions. A year ago, in correspondence with a brother geologist, I remarked that the criteria for a satisfactory classification of the glacial series depend upon the terminal edges and moraines. Every terminal moraine denotes necessarily a reädvance of the ice-sheet, or some temporary halt or slackening of its final retreat. Hence there must have been as many glacial stages as there are moraines, separated by as many gaps or *ad interim* deposits. Mr. Upham has described no less than twelve terminal moraines in his western field of labor; hence at least twenty-four successive phases of climate must be predicated. A still larger number of moraines, fifteen or more, are mapped by Mr. Leverett north of the Ohio river. It is likely that the mild intervals have varied in their importance; but whatever truths are involved in these premises, I remarked, I was ready to accept. I find now that these premises lead to the establishment of a grand unity, not unlike that of the Federal Union, *E pluribus unum*.

Prof. James Geikie has recently reclassified these epochs in the third edition of *The Great Ice Age*, noting the existence of thirteen of them. The first number is the early and greater part of the Pliocene, and the last is the present or only postglacial time, while between these are six glacial and five interglacial epochs, together making the Ice age. The first glacial and interglacial epochs (Nos. 2, 3) belong to the late Pliocene, being represented by the Weybourn crag and Chillesford clay for the glacial (2), and by the forest-bed of Cromer for the warmer terrane (3). Hence it is apparent that the Age of Ice is partly Pliocene and partly Pleistocene or Quaternary. In America, also, a great difficulty is removed by assigning epochs 2 and 3 to the latest Tertiary; for, in doing this, the Lafayette period is disposed of. It is so obviously related to the Ice age that Upham and others have referred it to the Quaternary era; but according to the Lyellian classification it must apparently be Pliocene. The Glacial age then belongs partly to the Pliocene and partly to the Pleistocene. Nothing except our hesitation to change

views once formulated should prevent us from adopting Geikie's leading. Indeed, he almost makes this reference himself, in his comments upon Prof. Chamberlin's preliminary correlation (page 774). He first identifies the Kansan stage with his second glacial epoch, and then asks whether there is not some deposit that can be correlated with the Weybourn crag, saying that "patches of 'old drift,' as we have learned, occur here and there buried under the accumulations of the Kansan stage." No one who has been familiar with the discussions of American geologists during the past forty years can fail to perceive that the Lafayette terrane is the deposit occupying this place, as it is both late Pliocene and glacial. It is true that Tuomey and Hilgard referred it to the Quaternary, but that was upon the assumption that the entire Ice age belonged there. If anyone hesitates to call the Lafayette gravels glacial in origin, let him explain how crystalline boulders, cobbles, and pebbles, from the northern Archæan can follow the Mississippi to its mouth (Petite Anse). They must have been transported a thousand miles, a greater distance than is known for any other glacial débris.

Further, the late Tertiary was a time of high continental elevation for both North America and northern Europe, and this has been thought to account for the origin of the cold climate. Professer Geikie states that every one of his glacial epochs commences with the land at a high stage of elevation. Owing, perhaps, to the weight of the accumulating ice, the crust of the earth sinks down, so that these epochs end with depression. Do not these facts prove a connection of the cold with elevation? And if so, was there any Pleistocene epoch when the conditions were more favorable than those of the Lafayette epoch for producing the cold? It is possible that the fact will be found even more than is thus claimed, and that the Lafayette may have been the time of maximum glaciation. Because of the existence of the Lafayette gravels, I have for many years insisted, in conversation and class instruction, that the entire Atlantic and Appalachian highlands were snow-clad at this time, the region being truthfully described in Dawson's humorous label of *Appalachia infelix*. Striation has been mentioned as occurring in the Virginia or North Carolina mountains by R. P. Stevens, in an old edition of Dana's Manual. While I agree with Hilgard and Upham in believing the Lafayette beds to have been laid down by torrential streams, those who think them estuarine or littoral may be equally well satisfied of the existence of glacial conditions.

Next let us see about the unity of the Ice age. In the later Pliocene the climate in high northern and southern latitudes became cold enough to originate glaciers which have never ceased to exist in the remoter centers of dispersion, like the Alps, Scandinavia, and some portions of both Americas. It is therefore a *single period*, characterized by extreme and continuous cold. The refrigeration commenced gradually, and after a warm interval, culminated in the second or Kansan epoch; since which time the colder stages have been less and less extreme. Our winters, with their alternate spells of freezing and thawing, but having a culmination about the first of February, may illustrate the varying con-

ditions of the earth's great winter. The dominant feature of the eleven epochs of Geikie is coldness, which was a marked change from the earlier conditions in the same latitudes. Ice, however, was not universal, and did not characterize the tropical regions of the earth. Other principles must be employed in the classification of the later epochs about the equatorial regions.

This view of unity is opposed to an early advocacy of duality, which perhaps now might not be insisted upon, with the great increase of knowledge. McGee's opinions in 1888, regarding the history of the Quaternary (Am. Jour. Sci., III, vol. xxxv, p. 463) may be cited for an example. "Collectively the two series of deposits indicate that the Quaternary consisted of two and only two great epochs of cold (the later comprising two or more sub-epochs); that these epochs were separated by an interval three, five or ten times as long as the postglacial interval; that the earlier cold endured much the longer: that the earlier cold was the less intense and the resulting ice-sheet stopped short (in the Atlantic slope) of the limit reached by the later; that the earlier glaciation was accompanied by much the greater submergence, exceeding 400 feet at the mouth of the Hudson and extending 500 miles southward, while that of the later reached but a tithe of that depth or southing; and that during the long interglacial interval the condition of land and sea was much as at present." This idea of duality may have been derived from an attempt to correlate the eastern phenomena with the two cold epochs inferred for the deposits in the basins of lakes Bonneville and Lahonton. It is noteworthy that Gilbert found only a short interglacial phase in Utah, which did not correspond with the one just mentioned for the east. It seems to me that the two moist maxima of the Great Basin, with their short interval, can be best correlated with the two greatest successive glacial epochs, as the Lafayette and Kansan. The later stages may not have been sufficiently intense to affect the extreme dryness of the far west.

It seems clear then that the Lafayette may represent the first glacial epoch, the Kansan the second, the Iowan the third, and the Wisconsin the fourth. At present it will be profitless to attempt to disentangle the succession of moraines in Ontario, New York, and New England, or at least I will not attempt it. Perhaps the greatest of the northern New England moraines, which, I have thought, may be traced from the Androscoggin lakes to lake Champlain, and which has been noticed in northern New York by Mr. S. P. Baldwin, will be found to continue westerly north of the Adirondacks into Ontario and to approach the interglacial beds of Scarboro'. What an interminable series of moraines there must be between New England and the remotest Laurentide pile of glaciated débris!

The new correlation must give us a Champlain glacial epoch, perhaps the fifth or sixth of the scheme. I think the warm Scarboro climate cannot be correlated with the arctic Champlain cold. Recalling the common fact that the European glacial epochs terminated with depression, it is obvious that the Champlain-St. Lawrence estuary may have

been a cold body of water into which glaciers discharged bergs. It is not easy to understand the presence of the boreal mollusca upon any other basis. The submergence lessened as time progressed, for the Leda clays are overlain by the Saxicava sands. With this arctic sea I would associate the local glaciers of the White and Green mountains, as well as those described by me in Maine, and others described by Canadian geologists in New Brunswick and Quebec. The fossiliferous strata are in some places covered by a till with large, more or less rounded boulders, on the coast of Maine and on the sides of the St. Lawrence valley in Quebec. Sir William Dawson speaks of it as a "second boulder drift associated with the Saxicava sand, and apparently resting on the terranes cut out of the older clays." If we consider that Dawson confines his description of the "Canadian Ice Age" to the continent as it was in this Champlain glacial epoch, we can accept his conclusions as truthful. It was a cold ocean, with floating ice and glaciers discharging from both the north and the south.

Ells and Chalmers, of the Canadian Geological Survey, have represented that the elevated land of New England and adjacent parts of Canada and New Brunswick was a center of dispersion for glaciers, and that no ice ever passed from the St. Lawrence valley over New England. Not to be misunderstood, I will quote from Ells, in the Canadian Report for 1886, page 44J: "The theory of a universal ice-sheet of many hundreds of feet in thickness does not appear to meet with much support as applied to this region. Proceeding southeast from the St. Lawrence basin, three principal ridges,....with elevations from 1,000 to nearly 4,000 feet above the sea, would have to be surmounted, which would require a propelling force imparted to the glacier, the source of which cannot be found in any great continental elevation related to the St. Lawrence valley. The great diversity also observable in the direction of the striæ at different points would appear to be opposed to this theory, for over a great portion of the eastern Cambro-Silurian area, there is a general course either to the southeast or northwest. If we accept the former course as that in which the ice passed, we must explain the manner in which the ice-sheet overcame the gradual ascent from the valleys of the Massawippi and St. Francis rivers, which have an elevation of 550 feet above the sea level, to the height of land on the Maine border, which reaches an elevation of from 1,800 to 3,800 feet. The theory which ignores for the most part the existence of the great continental ice-sheet presupposes the presence of local glaciers which formed along the summits and crests of the principal mountain ranges, from which the ice descended in either direction, influenced largely by existing topographical features."

The following notes from Mr. Ells' report for 1887 (page 100K) further illustrate his views: "Among the most interesting surface features in this section is the presence of scattered boulders of Laurentian rocks, gneiss, labradorite, limestones, etc." These have been used for building a church; and the elevation of the boulders was from 450 to 600 feet above the St. Lawrence. Similar boulders occur farther inland, both

on the approximately level country of the Cambrian, and on the most elevated ground, as Harvey hill, at 1,500 feet. Scattered pieces of gneiss here must have come from the north side of the St. Lawrence. "It is difficult to conceive, either on the theory of local glaciers or on that of a great ice-sheet, how these scattered boulders could have been deposited on the high levels of the interior, since on the former hypothesis the local glacier could have had no connection with the source of the boulders, and on the latter the ice-markings indicate that the course of the glacier could not have carried boulders from the hills along the north side of the St. Lawrence, across the great valley of that river, to the crest of the opposite ridges 1,500 feet or more above the sea level." The alternative theory, which he advocates, is that of submergence and the transportation by floating ice.

The difficulty of the transport of boulders from lower to higher levels is not a proof that floating ice did the work. I shall only aggravate Mr. Ells' difficulty by citing several cases that have fallen under my observation, of similar transport on the highlands, which go to prove that the general movement of the ice in its maximum development was to the southeast, and from the lower St. Lawrence level to the highest New England watershed.

1. Boulders ten feet in diameter of the peculiar breccia of Owl's Head, on Lake Memphremagog, have been carried to a hight of 1,700 feet in Brownington, Vt. This has involved sixteen or seventeen miles of transportation southward and as much as 900 feet of elevation. (Vt. Report, vol. I, p. 63.)

2. Several boulders of Laurentian gneiss, each about a foot in length, were noted by me in Clarkesville, N. H., some fifteen to seventeen miles south of the international boundary. In the same neighborhood are many small boulders of jasper, recognizable as originating from the auriferous range passing through Sherbrooke, 30 or 40 miles away at the north. I made no special search for these boulders, and only noted them incidentally.

3. The same, only larger and quite abundant, have been noted east of the Grand Trunk railway in northeastern Vermont at an altitude of 1,800 feet. They are very common in Norton, Vt.

4. In my first report upon the Geology of Maine (1862, page 416), I described blocks of Laurentian gneiss, twelve feet in length, upon the hills back from Fort Kent, Me., upon a southern slope. This was more than 1,000 feet above the sea, and the southward transport probably exceeded one hundred miles.

5. Recent thorough studies of the White mountain watershed (Bulletin, G. S. A., vol. v, pp. 35-37) prove that this highest range in New England has been glaciated from the northwest on every summit and in every col, and that fragments of rocks from the northwest are everywhere upon them. No Laurentian or Canadian rocks have yet been recognized upon them, but there are cases of elevation of more than 3,000 feet, and transport of 25 to 30 miles southeastward

6. Mt. Katahdin, a mile high, in northern [illegible] covered to a

hight of 4,000 feet by boulders of fossiliferous sandstones, which occur in place on the north and northwest. The mountain itself is composed of granite, but none of the granite is found on the northwest side. The fossiliferous blocks are found southward all over the state, down to the seashore.

The doctrine of local glaciers in northern Maine was advocated by me in 1861-'62. Glacialists have not quoted this, perhaps because at the same time I held the iceberg theory to account for the general drift. All the statements then made about the local glaciers of the St. John and other valleys were correct. I presume that with the recognition of numerous stages constituting together the Ice age, glacialists will be more favorable to my advocacy of the abundance of glaciers in New England during the closing part of the period, distinct from the great mass of the ice. However, I cannot accept Mr. Ells' views of the northwestward movement of the ice in the neighborhood of lake Memphremagog. The movement there was to the east of south. Owl's Head has been traversed by the same movement and could not have been of itself a center of dispersion. C. H. Hitchcock.

Hanover, N. H., March 14, 1895.

PERSONAL AND SCIENTIFIC NEWS.

The board of managers of the Iowa Geological Survey at its April meeting elected Mr. H. F. Bain assistant state geologist in place of Dr. Charles R. Keyes who recently resigned to take charge of the Missouri Survey. Mr. Bain has been an assistant geologist since the organization of the survey three years ago and is thoroughly familiar with the details and workings. He has pushed his investigations with great vigor and foresight and some of the results of his efforts are soon to appear in the forthcoming volume IV of the Iowa Survey now in press. This work will occupy the greater portion of a large quarto volume, illustrated by several colored maps, plates and numerous cuts.

The legislature of Missouri has given the Geological Survey of that state its regular appropriation. The bill for the continuance of the work passed both houses without a dissenting vote. In the senate $6,000 was added to the amount allowed by the lower house and recommended by the senate committee on appropriations, which amendment also passed without opposition, but in joint conference of the two houses it was necessary for the senate to recede, owing to lack of funds available for the next two years. Of all the appropriations made that of the survey was the only one which was not cut from the original amount asked for.

IN ADDITION TO THE AMOUNT GRANTED TO THE MISSOURI GEOLOGICAL SURVEY the legislature of that state also appropriated $20,000 for the completion of the topographic survey of southeastern Missouri for the purpose of reclaiming swamp lands. This is a work which has been in progress for several years independent of the Geological Survey. The amount allowed was with the understanding that it would complete the work and no more be asked for. In the future this allotment will be expended under the direction of the Geological Survey.

THE UNIVERSITY OF CHICAGO has purchased the paleontological collection of Mr. U. P. James, the paleontologist of Cincinnati. This collection contains many types and unique specimens and will soon be made accessible to students. It is especially rich in fossils from the Cincinnati group.

MISS FLORENCE BASCOM, PH.D., for the past two years a member of the corps of instructors in the geological department of the University of Ohio, has accepted a position in Bryn Mawr University. Dr. Bascom's record as a teacher and her thorough geological training assure the success of the department of geology at Bryn Mawr under her direction.

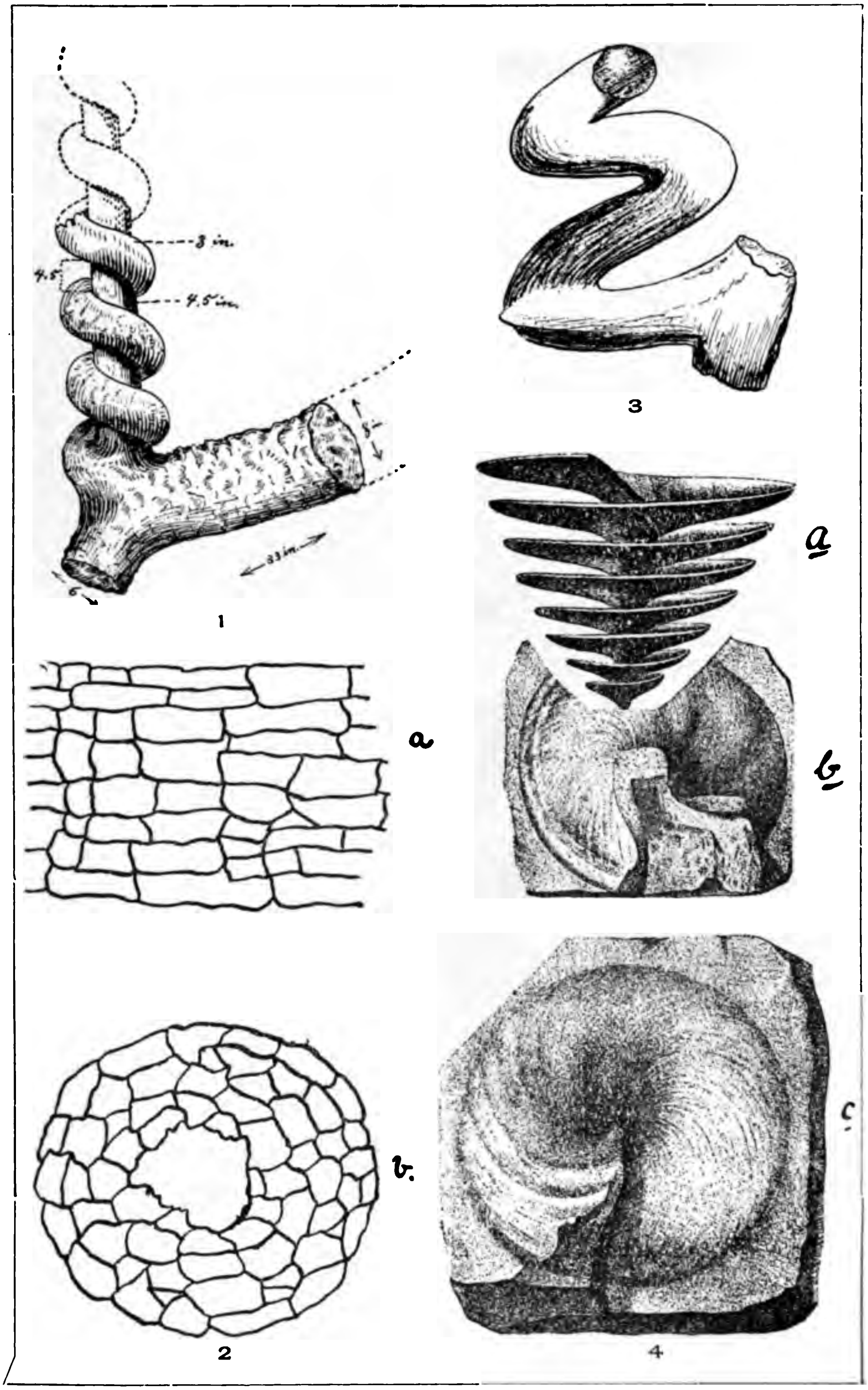
PROF. N. H. WINCHELL, MANAGING EDITOR OF THIS JOURNAL and state geologist of Minnesota since 1872, sailed from New York on the 17th of April. He expects to spend a year in Europe in geological study and investigation. During his absence Dr. U. S. Grant will look after the interests of the Minnesota Survey and of the AMERICAN GEOLOGIST.

MR. WARREN UPHAM, recently of the Minnesota Geological Survey, has removed to Cleveland, Ohio, to accept the position of librarian for the Western Reserve Historical Society.

HENRY B. NASON, for twenty-eight years professor of mineralogy and metallurgy in the Rensselaer Polytechnic Institute at Troy, N. Y., died January 18. He was born at Foxboro, Mass., in 1831, graduated at Amherst in 1855 and at Göttingen in 1857. From 1858 to 1866 he was professor of natural science and chemistry at Beloit college, Wisconsin. Three years ago he suffered a slight attack of apoplexy, the return of which terminated his singularly honored and successful career.

PROF. FRANZ POSEPNY, OF VIENNA, died on March 27th. For ten years he held the professorship of the Science of Mineral Deposits in the Mining Academy of Przibram. Prof. Posepny was well known to Americans through his elaborate treatise on the "Genesis of Ore Deposits," presented at the Chicago meeting of the American Institute of Mining Engineers and published in volume XXIII of the Transactions of the Institute.

PROF. JAMES D. DANA died on April 14th. In a future number we hope to give an account of the life and work of this distinguished geologist.



DAIMONELIX AND ALLIED FORMS.

THE

AMERICAN GEOLOGIST.

VOL. XV. JUNE, 1895. No. 6.

REMARKS ON DAIMONELIX, OR "DEVIL'S CORKSCREW," AND ALLIED FOSSILS.*

By JOSEPH T. JAMES, M. Sc., F. G. S. A., etc., Washington, D. C.

(Plates XI and XII.)

In the summer of 1891, Prof. Erwin H. Barbour, of the University of Nebraska, Lincoln, during a visit to the "Bad lands" of northwestern Nebraska, obtained some specimens of a remarkable fossil. It had long been known to ranchmen as the "Devil's corkscrew," but previous to Prof. Barbour's visit had not been known to the scientific world. The first account of the fossil appeared in "Science" for February 19, 1892,† and in this preliminary notice the name *Daimonelix* was proposed. They were gigantic and grotesque objects, and ever since their first notice they have been objects of wonder and speculation. Since his first visit, Prof. Barbour has twice re-visited the locality and has secured many other specimens. These have been diligently studied by him and, as a result, we have two other papers‡ from his pen; one published under date of July, 1892, and the other, July, 1894. The latter has just been distributed (March, 1895). In addition to these papers a popular article by Mr. F. C. Kenyon

*Read before the Biological Society of Washington, March 23, 1895.

†Notice of new gigantic fossils. Science, vol. XIX, pp. 99-100.

‡Notes on a new order of gigantic fossils. University [of Nebraska] Studies, vol. I, no. 4. pp. 301-335. pl. 6. July, 1882. Additional notes on the new fossil, *Daimonelix*. Its mode of occurrence, its gross and minute structure. Ibid, vol. II, no. 1, pp. 1-16, pl. 12, July, 1894.

has appeared in the American Naturalist.* In view of the extraordinary character of the fossils, a review of the papers will be of interest.

The typical species of the genus is described as possessing an obliquely ascending rhizome-like portion, varying from 8 to 18 inches in diameter and from 5 to 8 feet in length. The free extremity is generally broken off and is more or less friable, but from the opposite end there arises an axis, or perpendicular stem, around which is a regular stone coil. (Pl. XI, Fig. 1.) On the opposite side to that from which the axis and coil arise is frequently a short projection, seldom more than 10 or 15 inches long. This part, taken in connection with the coil and the long projection at the other end, has given rise to the common name corkscrew, which it most strikingly resembles. The coil twines to the right in some instances and to the left in others, the two at times being in close juxtaposition in the beds. In other examples the coil is more or less double; it may be carinated, or it may even lack the central axis around which to coil. These are all variations of the same general structure and have been given specific names by Prof. Barbour.

The outer surface of the fossils is a "tangle of ramifying, intertwining tubules, varying in diameter from $\frac{1}{64}$ to $\frac{1}{8}$ of an inch. Some are a full fourth of an inch, although the average is about $\frac{1}{32}$ of an inch." The tubules are more densely clustered toward the center of the fossil, until a solid, white compact wall is reached, which encloses a central core of rock, irregularly traversed longitudinally by large tubules, and transversely by minute ones.

Examination of these tubules shows a cellular structure very plant-like in character. A longitudinal section (Pl. XI, Fig. 2*a*) shows the cells to be elongated and piled one on top of the other like the cells of palisade tissue of a living leaf. A cross section (Pl. XI, Fig. 2*b*) shows a series of irregularly polygonal cells, arranged at times about a central space.

The locality in which these fossils occur is in the extreme northwestern corner of Nebraska in the neighborhood of Harrison, Sioux county, on the Fremont, Elkhorn and Missouri Valley R. R. It is in the midst of the so-called Bad lands,

*In the region of the new fossil, *Daemonelix*. Amer. Nat., vol. XXIX, pp. 213-227, March, 1895.

which have given to science so many wonderful forms of life. The "corkscrews," as far as now known, occur over an area of 400 or 500 square miles. They have a vertical range of from 150 to 200 feet, according to Barbour. The tops of the hills are capped with sandstone, which is underlain by a compact layer of light yellow flint, 18 inches or 2 feet thick. This is quarried for a building stone. Below this is a very homogeneous and more or less coherent sand-rock, from 800 to 1,000 feet thick, under which again is a layer of marl. The continuation of this marl to the northward forms the Bad lands of Hat Creek basin. It is in the upper 200 feet of the sand-rock underlying the flint that *Daimonelix* occurs.

Beyond a mention of the Miocene in connection with the fossils, Prof. Barbour does not discuss their geological position. But Dr. J. L. Wortman, in a paper read before the New York Academy of Sciences, Feb. 11, 1895, and reported in Science, (n. ser., vol. I, p. 306,) positively identifies the formation with the Loup Fork division of the upper Miocene. He agrees with Prof. Barbour that the beds are of sedimentary origin.

The opinions that have been advanced as to the nature of these fossils are various. Some have considered them as burrows of animals; some as having been made by shells; some thought them to be roots of plants, and some said they were Algæ. That they are really of vegetable origin seems to be settled by the results of Barbour's studies of the tubules before mentioned, which show evident traces of plant structure.

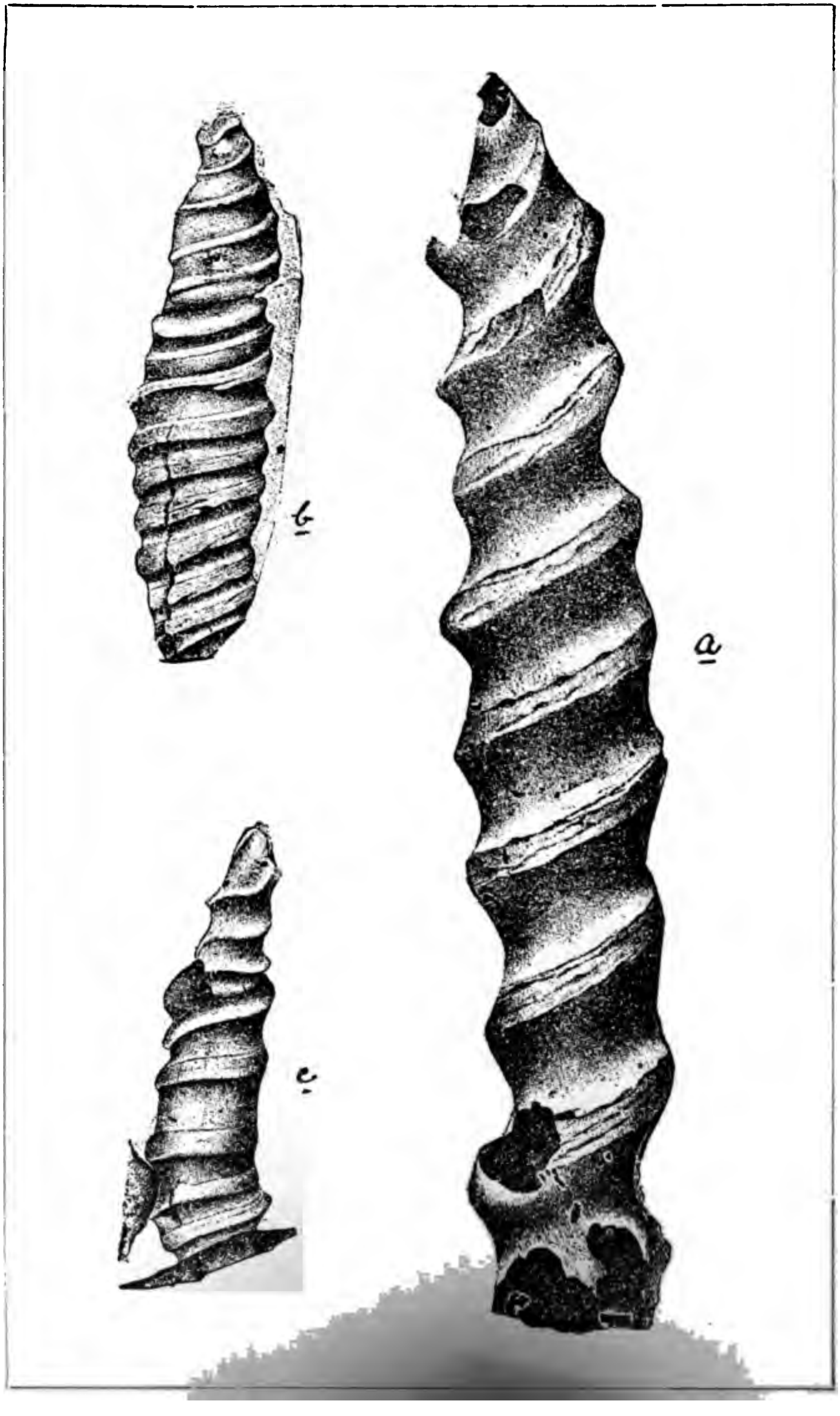
One point seems to have been overlooked by all who have written upon them. They have been considered as unique and without resemblance to any other known fossils. As a matter of fact, however, they are not unique except in point of size. Similar fossils were described by Oswald Heer in 1865* who called them "screw-stones," and who published the figure here given. (Pl. XI, Fig. 3.) He states that the fossils occur in Miocene strata in different localities in Switzerland and describes them as rods about the thickness of the finger, upon which are situated spirally wound branches of the same thickness. He considered them to have been made by boring shells, a number living together, and sending out the spiral

*Die Urwelt der Schweiz, p. 438. 1865.

tubes, each of which served as a dwelling place. He states that Karl Mayer had found a species of *Lutraria* (*L. senna*) in one of them. He also believed the tubes were bored in the sediment after its deposition and solidification. Heer does not give the fossils any name but that of "screw-stones." While he was probably wrong in his interpretation of the specimens, it is interesting to note their remarkable resemblance to specimens of *Daimonelix*.

Two years before this publication by Heer, Prof. James Hall published an interesting paper on *Spirophyton**. The forms had originally been noted by Vanuxem many years previous, and some had been described by him as the "retort" and "cocktail" fucoids. Although regarded by him as of vegetable origin, Vanuxem did not advance any proof in support of the idea, and it remained for Hall to indicate a possible mode of growth. Three of his illustrations are here reproduced. (Plate XI, Fig. 4, *a*, *b*, *c*.) In his remarks, Hall states that the form of the fossil was that of a spiral frond growing upward from a small base, gradually expanding in its successive volutions. The axis is generally thickened. He says: "I have ascertained this mode of growth and form of the fossil by separating successive laminæ of the shale, and tracing the continuation of the same frond upward, as it appears in the enlarging discs upon the successive surfaces. In this manner they have been traced from where the diameter is less than one inch, and apparently near their origin; and thence through the gradually expanding volutions till they have reached the diameter of several inches, the spaces between the volutions being several times greater than the thickness of the frond. The volutions and the form of the disc often, and perhaps usually, continue very regular till the turns have reached a diameter of four or five inches, while the larger fronds not infrequently present irregularities and distortions, both from unequal growth and from accident, evidently having been very flexible and easily disturbed." "These bodies have grown only in quiet positions, as proved by the fine shaly and slowly deposited matter

*Observations upon some spiral-growing fucoidal remains of the Palæozoic rocks of New York. Sixteenth Ann. Rept. Regents Univ. of N. Y., Albany, pp. 76-83, pl. and figs., 1863.


b
a
c

which envelopes them." Nothing approaching a perfect specimen has ever been found in New York or other localities where *Spirophyton* occurs. A comparison of Hall's figures showing the upper and lower surface of a whorl of *S. typum* is very like a figure given by Barbour, as shown below. (Fig. 1.) There seems good reason to refer both to the same class of organisms.

FIG. 1. View of one coil of *Daimonelix robusta* Barbour. (After Barbour.)

A number of generic names have been given to the fossils described by Hall but *Taonurus* of Fischer-Ooster, proposed in 1858, is the same as Hall's *Spirophyton* and has priority by five years.

There is still another genus of fossils which has evident affinity to those mentioned above. In 1883 Prof. J. S. Newberry read a paper before the New York Academy of Science* in which he described a new genus of "screw-like" fossils from the Chemung rocks of New York, under the name of *Spiraxis* Two species, *S. major* and *S. randalli*, were described. They were simply casts in sandstone without any trace of animal matter. (Pl. XII.) It was supposed that they might be Algæ or sponges but no definite conclusion was reached. They have also been compared to eggs of fossil fishes. The rocks in which they occur are full of impressions of *Spirophyton* (or *Taonurus*) and this is significant in the light of our present knowledge. When we consider the theoretical plant of Hall and the presence of the spiral fossil of Newberry associated with fragments of *Taonurus*, the inference seems to be fair that the relationship is very close. Again when we note the

*Descriptions of some peculiar screw-like fossils from the Chemung rocks. Ann. N. Y. Acad. Nat. Sci., vol. 3, pp. 217-220, 1885.

presence of plant-like cells on and in *Daimonelix* and the similar mode of growth to *Taonurus* we seem still further justified in grouping them together. The fact that they are separated by a great time interval does not, in our opinion, militate against their being placed together in the same order.

It is also interesting to note the occurrence in Miocene rocks of Switzerland of fossils so very like others of Miocene age in Nebraska.

DESCRIPTION OF PLATES.

PLATE XI.

FIGURE 1. *Daimonelix circumaxilis* Barbour. (After Barbour.)

FIGURE 2. Sections of tubules of *Daimonelix*. *a*, Longitudinal section: *b*, cross section. (After Barbour.)

FIGURE 3. "Screw-stone," one-half natural size. (After Heer.)

FIGURE 4. *Spirophyton typum* Hall. *a*, Restoration of species. *b*, lower side of frond two volutions below *c*, which represents the upper side of a volution, the sixth or seventh from the base. (After Hall.)

PLATE XII.

a, *Spiraxis major* Newb. *b* and *c*, *S. randalli* Newb.

A CONTRIBUTION TO THE GEOLOGY OF THE COAST RANGES.

By ANDREW C. LAWSON, Berkeley, Cal.

INTRODUCTION.

During the past four years the writer has given much of his spare time to an inquiry into the geology of the Coast ranges of California. This work has taken the form of reconnaissance explorations in the southern and northern portions of the state and of more detailed studies in the vicinity of the bay of San Francisco. A portion of the latter work has been done on behalf of the U. S. Geological Survey and by means of the excellent topographic maps which the Director of the Survey, at the request of the geological department of the University of California, caused to be made of this region. In the prosecution of this work the peninsula of San Francisco has been geologically mapped and modelled on a scale of two inches to the mile from Lat. 37° 30′ northward to the Golden Gate. The results of the field work have been summarized in a paper now in the hands of the Director of the Geological Survey for publication in his fifteenth annual re-

port. The present note is intended as a brief abstract of that paper, which shares the usual delay attendant upon government reports.

GENERAL OUTLINE OF GEOLOGY.

The investigation of the geology of the San Francisco peninsula has revealed the existence of many sedimentary and igneous formations. The grouping of these in accordance with well known geological principles reduces them to seven groups, which, by reason of the technical sense attaching to the word *group*, are here referred to as *terranes*. This term is used as a necessary expression for any formation or group of formations in connection with the areal distribution of the same. These seven terranes in the order of their geological age comprise:

1. *Crystalline limestone*, age unknown.
2. *Granite*, referred to as the Montara granite, intrusive in the crystalline limestone.
3. The *Franciscan series*, an assemblage of sedimentary and volcanic rocks of great thickness, with which are associated various basic intrusives, notably peridotite serpentines. This series rests upon the eroded surface of the Montara granite.
4. A formation of light colored, cavernous-weathering sandstone which is supposed, doubtfully, to be of *Tejon* (*Eocene*) age.
5. The *Monterey series* (*Miocene*), chiefly white, siliceous, bituminous shale, practically devoid of detrital matter. (Nos. 4 and 5 together repose indifferently upon the Montara granite and upon the worn surface of the Franciscan strata just to the south of Lat. 37° 30′.)
6. The *Merced series* (*Pliocene*), a thick volume of sediments with one stratum of volcanic ash deposited after the erosion of the Miocene.
7. The Terrace formations, Pleistocene and later.

Of these seven terranes, the Montara granite, the Franciscan series and the Merced series are the dominant features of the geology of the peninsula north of the parallel of latitude mentioned. South of that line in the Santa Cruz mountains the Monterey series is largely developed. All seven terranes are important factors in the general geology of the Coast ranges. The consideration of the petrography and tectonic of these various terranes, both as a whole and as regards their constituent sedimentary and igneous formations, opens out many interesting problems. These have to do chiefly with conditions of deposition, metamorphism, diastrophism and geomorphogeny. The Montara granite introduces us to the still unsolved problem of the development of batholitic mag-

mas. In the Franciscan series we have, in addition to the detrital rocks, foraminiferal limestones and great formations of very peculiarly bedded radiolarian cherts. The conditions governing the deposition of these rocks are not clear, but there are strong suggestions that they are essentially chemical deposits, although containing organic forms. In the same series certain rocks held by some earlier writers to be metamorphic sediments are shown to be true igneous rocks, chiefly contemporaneous volcanic extravasations. The serpentines, which have also been held to be metamorphic sediments, are shown to be altered conditions of peridotites or pyroxenites, in harmony with the results already announced by Palache* and Ransome.† They are intrusive in the Franciscan series in the form of dikes and laccolitic lenses. There are certain highly crystalline schists which form part of the series. These are shown to be altered forms of the normal sedimentary and volcanic rocks of the series. They are associated with the serpentines and other basic intrusives, and the hypothesis is advanced that they represent contact zones of local metamorphism on the borders of these intrusives, which hypothesis has been greatly strengthened by the excellent work of Ransome on the geology of Angel island, the results of which have already been published.‡ Reconnaissance observations have suggested the extension of this hypothesis to the effect that none of the crystalline schists of the Coast ranges are products of regional metamorphism as that term is commonly understood, but that they are contact zones of irruptive masses.

Apart from the diastrophic disturbances, foldings and uplifts which mark time intervals between the different terranes, the field, from an orogenic point of view, resolves itself into two great fault blocks, each tilted to the northeast, with a structural valley between. The sculpture of these blocks during the remarkable oscillations of the coast in post-Pliocene time, together with the development of certain minor constructional forms, yields us the geomorphy of the present time. The history of the diastrophic movements which have af-

*Bull. Dept. Geol. Univ. Cal., vol. I, no. 5.

†Ibid., vol. I, no. 7.

‡Loc. cit.

fected the field and which have all contributed to and been part of the process of evolution of this modern geomorphy is astonishingly incisive and complex.

Crystalline Limestone.

Only a very small remnant of this formation occurs within the limits of our field, although it is extensively developed, in a similar relation to the same granite as that of Montara, in the Santa Cruz mountains to the south. The marble occurs as a small patch on the southwest side of Pilarcitos canon below the stone dam, and is either a large inclusion in the granite or is a portion of the formation which once arched over the intrusive mass. It is very clearly a remnant of a pre-granite formation which was invaded by the granite batholite. Like many other marbles associated with the granites of the southern Coast ranges, it is charged with scales of graphite.

Montara Granite.

The granite constitutes the mass of the bold mountainous ridge which rises abruptly from the shore in the southwestern part of the peninsula to an elevation of nearly 2,000 feet. It forms an oval area whose major axis is ten miles in length and has a northwest and southeast trend parallel to the general trend of the Coast ranges. It extends from point San Pedro to a little beyond the pass above Crystals Springs lake. The maximum transverse diameter of the area is four miles. The granite is in general a coarse gray, hornblende-biotite granite, hornblende preponderating. Locally the biotite is the chief dark constituent. Various subordinate facies of the rock occur. These are due to the relative proportions in which the essential constituents appear, the occasional porphyritic character of the hornblende, the local abundance of the accessory constituent titanite, and the deformation of the rock by shearing action, resulting in rude foliation associated with the development of secondary biotite from the hornblende. The prevalent facies is very quartzose and has plagioclase apparently not less abundant than orthoclase. In various parts of the mass basic secretions appear in the form of dark patches. Pegmatitic and aplitic dikes traverse the mountain in all possible directions, sometimes in well defined fissures, sometimes in exceedingly irregular intrusions. The aplites and pegmatites are not sharply separable but may grade into one

another in the same dike. In its general characters the granite of Montara is identical with that of the Farallones and of Tomales point to the north of the Golden Gate. It is also identical petrographically with the granite of the Santa Cruz mountains to the south, and is undoubtedly continuous with it beneath the mantle of Tertiary strata which covers portions of the range. Montara mountain thus appears to lie about midway in a range of granite which may be traced in a series of very extensive exposures from Bodega Head to the town of Santa Cruz, a distance of over 100 miles. This granite is known at various places to be intrusive in a pre-existing sedimentary terrane. The granite mass is clearly of the nature of a great batholite, which has invaded the crust from below and from its extensive exposures at Montara mountain, where it has been first studied, it may be designated the *Montara batholite.*

The Franciscan Series.

The Franciscan series reposes upon the worn surface of the Montara granite, and the basal strata of the series have originated from its waste, being conglomerates with granite boulders and coarse grits composed of the granitic débris. What extent of geological time is represented by the interval between the invasion of the region by the Montara batholite and the deposition of the basal Franciscan rocks upon its eroded surface is not yet determined. The simplest and most natural hypothesis that suggests itself is, that the granite corresponds in age with that of the Sierra Nevada, and this hypothesis has not yet been exhausted of its strong probability of truth. The granites of the Sierra in so far as their age is known are clearly post-Jurassic. Granites of about this age are extensively developed all along the west coast of North America from Alaska southward. The granites of the southern and northern Coast ranges seem to be geologically continuous with those of the Sierra Nevada. The fact that the Sierra are separated from the Coast ranges by the valley of California is immaterial to the discussion, since the latter is clearly a delta-filled geo-syncline of late Tertiary or post-Tertiary origin. There is therefore a strong presumption in favor of the view that the granites of the Coast ranges and those of the Sierra Nevada are of common origin and common history

This presumption must be kept steadily in view till it is negatived by positive evidence.

The rocks of the Franciscan series occupy two distinct areas, one on either side of Merced valley, which traverses the peninsula obliquely from northwest to southeast. The southern area is a belt of from four to five miles wide which flanks Montara mountain on its northeast side and conforms to its strike. The belt extends from the steeper slopes of the mountain out to the edge of the Merced valley, and farther south, where the terrane is not now represented, out to the shores of the bay. The northern area of the Franciscan terrane lies in the triangular section of the peninsula which is situated between Merced valley, the Golden Gate and the bay of San Francisco. The formations of the series, with the associated eruptives occupy all of the seemingly irregular cluster of peaks and ridges within the area indicated. Other rocks, however, share with the Franciscan series the occupancy of the area. The terrace formations and the sand dunes wind in among the hills and ridges, and cover their lower flanks.

The various petrographically discrete formations which make up the Franciscan series are:

1. A basal formation of conglomerates, coarse grits, sandstones, shaly sandstones, shales and argillaceous limestones.

2. The "San Francisco sandstone," the dominant sedimentary formation of the series; a moderately fine grained sandstone, fairly uniform in character over large areas, with subordinate beds of shale and conglomerate. The sandstone is uniform not only in its lateral extension but also vertically for great thicknesses. It is interbedded with formations 3, 4 and 5 named below.

3. Foraminiferal limestones.

4. Radiolarian cherts.

5. Volcanic rocks including basaltic lavas and pyroclastic accumulations. There are besides these, intrusive rocks of a corresponding character, some of which are probably connected with these extravasations, and also intrusive peridotites and pyroxenites now serpentinized.

6. Silica-carbonate sinter.

In addition to these there are certain metamorphic schists which arise from the local alteration of the sedimentary or volcanic formations and do not constitute a separate formation according to the writer's interpretation of them.

Of these various kinds of rock those classed under 1 and 2

call for no special comment here. The others may be briefly noticed.

Foraminiferal Limestone.—This rock has a fairly constant petrographical character although it occurs in at least two horizons. The lower and more persistent and voluminous of the two formations is nearly pure limestone; the upper contains a notable proportion of clay. There are several hundred feet of sandstone and other rocks between the two formations. In general it is a very compact rock resembling lithographic limestone. Its color is a light drab gray to dark gray. The rock is generally traversed by minute veinules of calcite intersecting in all directions without evidence of faulting, and by larger veins of dark-colored silica, usually an inch or two thick, traversing the rock parallel to the bedding, with occasional transverse veins. The Foraminifera are represented by clear hyaline spots ranging in size up to .5 mm., which, in favorable cases, may be observed with the lens to have the forms of shells. In thin section the limestone is a structureless cryptocrystalline aggregate which between crossed nicols appears light, whitish gray, due to compensatory polarization. The sections afford no evidence of deformation nor are the Foraminifera deformed by dynamic action. The latter are quite discrete from the matrix in which they are imbedded. The rock appears to be a chemical deposit in which Foraminifera were more or less sporadically entombed.

Radiolarian Cherts.—These are hard, flinty, siliceous rocks of a prevailingly brownish red color. Yellow and green colors are not uncommon, however, and other colors are more rarely met with. The most remarkable feature of these cherts is their bedding. This is well displayed in numerous favorable sections. The essential feature of the bedding is the alternation of thin sheets of chert with partings of shale. The sheets of chert range generally from one to three or four inches in thickness, with an average of perhaps two or three inches. Occasionally there are thicker beds. The shaly partings vary usually from about one eighth to one half an inch in thickness. As the sections are in places several hundred feet thick they present the remarkable phenomenon of an alternation of thousands of these chert sheets with the corresponding layers of shale.

These cherts are in many cases true jaspers, but in others the silica is chiefly amorphous though of the same excessively hard and flinty character. There are all gradations between the amorphous and the holocrystalline varieties and the transition is thought to represent a passage in time from an originally amorphous condition to the holocrystalline condition. In some few cases they pass into softer, earthy facies when the red pigment preponderates, and in other cases they pass locally into a quartz-rock resembling vein quartz. The Radiolaria in these cherts are apparent to the ordinary inspection, with the aid of a lens, as minute dots which are quite discrete from the matrix in which they are imbedded. Are these radiolarian cherts deep sea deposits? Are they wholly of organic origin? What is the explanation of their remarkable bedding? What was the rate of their accumulation? The suggestion that they are deep sea deposits is negatived by their interbedding with sandstones. The occurence of sharply discrete casts of radiolarian tests in a dense siliceous matrix which *usually* shows no evidence of being made up of organic débris casts doubt upon the supposition that the whole rock may be of organic origin. The sporadic occurrence of the cherts in this particular field at different stratigraphic horizons and throughout the Coast ranges generally also militates against the organic hypothesis. If the cherts are wholly organic they would have formed continuous sheets of great extent. They do not. They occur in the form of innumerable isolated areas, and the isolation cannot be ascribed to erosion. It is original. The silica of the cherts seems to have been originally an amorphous chemical precipitate, deposited at local centers on the sea bottom, in which radiolarian remains were sporadically entombed. Occasionally the silica is thickly charged with this débris. Usually it is not. The change which has taken place in the silica seems essentially to have been due to gradual crystallization analogous to the process of devitrification in glass, which change seems not to have affected the forms of the radiolarian remains. The most probable origin of the bulk of the silica of these cherts seems to the writer to have been sub-marine siliceous springs of solfataric character. This "crenitic" hypothesis offers a satisfactory explanation of the exceedingly irregular

stratigraphical and geographical distribution of these profoundly interesting rocks, as well as of their petrographical character. It suggests farther an explanation of the very remarkable bedding in the supposition that the supply of silica may have been rhythmically intermittant. We have as yet no measure of the rate of their accumulation.

Volcanic Rocks.—It would be out of place to attempt here a detailed petrographical description of the volcanic constituents of the Franciscan series. They are, in general, basaltic rocks in a more or less advanced state of alteration. Sometimes they are dense compact lavas, sometimes they are highly amygdaloidal. Occasionally they have the character of glass breccias, and pyroclastic accumulations are abundantly represented. These effusive rocks appear interstratified with the sedimentary strata at various horizons in beds varying in thickness from a few feet to several hundred feet.

Intrusive Rocks.—The igneous rocks intrusive in the Franciscan series may be classed under two heads. 1. Those of a diabasic or basaltic character, and (2) peridotite (sometimes pyroxenite) now serpentinized. Of the first class many are identical with the spheroidal and variolitic basalts of point Bonita, which have been described by Ransome*. Others are of the character of diabase or olivine diabase. While many of the occurrences of these rocks are clearly intrusive, there are other cases where it is very difficult to discriminate them from the contemporaneous effusives, and it is probable that part of them are genetically connected with the latter and represent a phase of the same volcanic activity. There are also some intrusives of very limited extent of the character of gabbros or diorites and one occurrence of a rock which may prove on further examination to belong to the bostonites.

The peridotites and pyroxenites, which, by well known process of alteration have given rise to the serpentines, form an important feature of the geology of the peninsula. There are two dominant ranges of the serpentine traversing the peninsula from northwest to southeast; and there are other subordinate occurrences having a similar trend. The field study of these serpentines shows that beyond any question they are of the nature of dikes, intrusive sheets and laccolitic

*Bull. Dept. Geol. Univ. Cal., vol. I, no. 3.

lenses. A detailed petrographical description of a typical occurrence of this serpentine has been given by Mr. Palache* and another occurrence has been investigated by Mr. Ransome†. Other occurrences have been petrographically examined by the writer with the same general result that they are referable to original olivine pyroxene rocks or to pyroxenites without olivine.

There are no other serpentines on the peninsula, nor, in the experience of the writer, elsewhere in the Coast ranges, which are not the alteration of products of intrusive peridotites or pyroxenites.

The serpentines are of later age than the basaltic and diabasic intrusives.

Silica-Carbonate Sinter.—This is a very curious rock which is somewhat characteristic of portions of the Coast ranges. It is a rusty,cellular-weathering mixture of opal and chalcedony with the carbonates of lime, magnesia and iron. It occurs in the San Francisco sandstone, and although not extensively developed on the peninsula, it occurs in considerable sheets in Aucella bearing sandstone in other portions of the ranges. It appears to be a chemical deposit, and its occurrence in extensive sheets roughly parallel with the bedding suggests that it is a contemporaneous deposit, but it may possibly be a vein formation. Its occurrence in the Aucella sandstones elsewhere and in the San Francisco sandstones of the peninsula is of inte[illegible] a possible factor in the correlation of these formations.

Metamorphic Schists.—These rocks although not extensively developed on the peninsula, are believed to be petrographically and genetically representative of the crystalline schists of the same series of rocks throughout the Coast ranges. They are chiefly glaucophane, hornblende or mica schists, with or without garnets and other accessory minerals. Quartz or feldspar, or both, are usually present. These metamorphic schists have a very limited distribution and this has a definite relation of dependence upon the occurrence of the intrusive peridotites and other basic irruptives. The schists are only known in the vicinity of these intrusives, and are frequently

*Bull. Dept. Geol. Univ. Cal., vol. I, no. 5.
†Loc. cit.

in immediate contact with them. Gradations may often be observed from the most crystalline of these schists into the normal sandstones and volcanic rocks of the series. The inference is unavoidable that the schists are the local zones of contact metamorphism due to the intrusion of the irruptive rocks. The extremely irregular distribution of the intensity of the metamorphosing action in these contact zones is very perplexing and makes the field study tedious in the extreme. But when the irregularity is recognized as a constant factor in the problem, the study is simplified. The association of glaucophane, or hornblende, or mica schists with intrusive peridotites and other basic irruptives, is, in the experience of the writer, constant through the Coast ranges. The best illustration of this association is afforded by Angel island, which has been thoroughly investigated by Mr. Ransome.* There can be no reasonable doubt but that the sporadic occurrences of schists throughout the Coast ranges in rocks similar to those of the San Francisco peninsula are but local contact zones. In a recent trip on horseback through the heart of the northern Coast ranges from Humboldt county to the Golden Gate, the writer saw this relation of schist and irruptive so repeatedly exemplified that he advances the hypothesis with the greatest confidence.

Correlation of the Franciscan Series.—The correlation of the Franciscan series cannot at present be satisfactorily settled. The paleontological evidence bearing on the question is as follows: (1) The occurrence of *Inoceramus* in the San Francisco sandstone of Alcatraz island as recorded by Whitney. (2) The discovery of a fragment of a shell, which, according to Mr. Stanton of the U. S. G. S., is either an *Inoceramus* or an *Aucella*, in the same formation south of San Mateo. (3) The occurrence at the base of the series on the flanks of Montara mountain of shells which Mr. Stanton has determined as probably belonging to *Pectunculus* and *Opis*, and others which resemble more recent species of *Venus*. (4) The Foraminifera of the foraminiferal limestone embrace, according to Mr. Charles Schuchert, the genera *Orbulina*, *Globigerina*, *Textularia* and *Rotalia*, and in the opinion of Prof. Walcott the association of forms indicates an association of

*Loc. cit.

forms not older than the Cretaceous. (5) In the radiolarian cherts Dr. C. Jennings Hinde has recognized at least ten genera similar to rocks of Cretaceous and Jurassic age in Europe. The general tendency of this paleontological evidence is to place the Franciscan series in the Cretaceous. This would harmonize with the suggestion thrown out on a former page that the granite upon which the series reposes is of post-Jurassic age. It is the opinion of both Whitney and Becker that the rocks of this series are of Cretaceous age. The writer reserves his opinion on the question till further evidence has been gathered, and is content for the present to point out that the evidence, such as it is, is confirmatory of the opinion of Whitney and Becker. It remains to be said, however, that the series as a whole is very probably older than the Knoxville Aucella horizon of California. The writer has no doubt upon this point, although he has not yet had an opportunity of revising the field evidence which led Becker to a contrary opinion; and if it be finally established that the Franciscan series is Cretaceous it must enlarge materially our conceptions of the volume of the lower Cretaceous in California.

Attention has been called to the fact that the Franciscan series comprises those rocks which Becker placed in the metamorphic or Knoxville division of the Cretaceous. Becker, however, grossly exaggerated the metamorphism of the Coast ranges. The rocks, which are clearly contemporaneous volcanic flows or subsequent igneous intrusions, he classed as metamorphic sediments under the designations *pseudo-diabase* and *pseudo-diorite*; the serpentines, which are unquestionably intrusive peridotites, he also classed as metamorphic sediments; the radiolarian cherts he regarded as metamorphosed, silicified shales. They are certainly not silicified shales, but original siliceous deposits intercalated with perfectly unaltered sandstones. If we cut out these three important groups of rocks from his appalling scheme of regional metamorphism it shrinks to more reasonable dimensions; for we have then left only the glaucophane schists, and these are but contact zones of basic intrusives. A fearful incubus is thus removed from Coast range geology.

Structure of the Franciscan Series.—The tectonic features

of the series as studied on the San Francisco peninsula may be very briefly summarized. As regards the volume of the series, the writer is not yet prepared to make any explicit statement, as the faulting of the region renders an estimate difficult. It is safe to say, however, that the series is several thousand feet thick. This volume of strata is folded generally in open, rather flat synclines and anticlines. In the southern part of the field, however, where the strata have been crowded up against the Montara granite, the folds are locally sharply compressed and at least one dominant syncline shows pronounced reversed dips. Faults are important features of the structure, but they are difficult to measure. Intense crushing is not a feature of the series, except locally where softer beds have been affected. Locally, also, intense plication occurs in the thin bedded radiolarian charts by reason of the ease with which these hard, brittle beds have moved on the shaly partings.

Tertiary Rocks.

Near Spanishtown, a little to the south of Lat. 37° 30′, sandstone supposed to be of Tejon age and the white siliceous shales of the Monterey series (Miocene) repose indifferently on the Montara granite and upon the Franciscan series unconformably. The relations are such as to indicate clearly a great interval of erosion between the close of the Franciscan sedimentation, and the deposition of the Tertiary strata. After the Miocene, a period of erosion intervened which removed the whole of the earlier Tertiary rocks from a large part of the region for we find a great thickness of Pliocene, Merced series, reposing on the Franciscan rocks and on the granite. This Merced series has been noticed in a former paper.* As has been shown there, the strata of this series to the thickness of over one mile are magnificently exposed in the sea-cliff south of the city of San Francisco and dip continuously throughout the section to the northeast. Since their deposition these Merced rocks have been profoundly affected by diastrophic movements and have been denuded from a large portion of the peninsula over which they were once spread.

*Bull. Dept. Geol. Univ. Cal., vol. I, no. 4.

POST-PLIOCENE DIASTROPHISM.

The San Francisco peninsula is composed of two great fault blocks, each tilted with a gentle slope to the northeast and having a precipitous fault scarp to the southwest. The more northern of these blocks extends from Merced valley to the Golden Gate, and the southwestern wall of the San Bruno mountains overlooking the valley is its fault scarp. The more southerly block lies between Merced valley and the coast south of San Pedro point.

The gently sloping back and the precipitous scarp of the block intersect in the crest of Montara mountain. The Merced strata form part of the sloping back of the Montara fault block and dip toward the fault plane which has dislocated the two blocks. These Merced beds must obviously have extended over the northern extremity of the peninsula prior to the faulting. There is now no trace of these beds to be found on the back of the block. They have been removed by erosion. This complete denudation of the Merced strata from the northern block and their abundant occurrence on the southern block up to an elevation of 700 feet above sea level indicate that the northern block is the older of the two. Its more advanced sculpture points to the same conclusion. It is believed, therefore, that the more northern block was thrown up and subjected to denudation before the Montara block came into existence as such. The differential throw of the San Bruno fault must be at least 7,000 feet.* Then came the Montara upthrust whereby the second block was tilted, the axis of uplift being parallel to that of the San Bruno uplift. At the close of these orogenic movements, the general altitude of the peninsula was much lower than at present, for we have excellent evidence of the emergence of both blocks in unison with the uplift of the whole Californian coast. Two particularly well characterized baselevel bench-marks serve to indicate pronounced stages of this uplift. These are dissected plateaux at about 1,200 feet and 700 feet; and, at lower levels, there are spread out on the slopes of the two blocks marine embankments which give a terraced character to the topography.

*That is on the assumption that the fault is normal. The fact that the normal character of the fault is assumed should not be lost sight of. So far as the field evidence is concerned it is possible that an over thrust might effect the same results.

These terrace formations are of very recent age and mantle over the trace of the San Bruno fault which dislocated the Merced series. Since the culmination of the general uplift subsidence to the extent of several hundred feet has ensued, as has been more fully described in a former paper.*

University of California, March 31st, 1895.

[CRUCIAL POINTS IN THE GEOLOGY OF THE LAKE SUPERIOR REGION. NO. 4.]

CANADIAN LOCALITIES OF THE TACONIC ERUPTIVES.

By N. H. WINCHELL, Minneapolis, Minn.

It is well known that under the name Hudson River group, and later under the term Quebec group, the rocks of the Taconic system were extensively traced out in Canada, between the Vermont state line and the St. Lawrence river. In general they pass through the "eastern townships." If we neglect the early Canadian classifications, which were vague and largely haphazard and have been abandoned, we find Dr. Selwyn, in 1877, clearly describing these rocks and assigning them a stratigraphic position between the Silurian and Laurentian,† *i. e.*, to the position of the typical or original Huronian, and their age as "probably Lower Cambrian." In this description he refers to the same position various eruptives with which the clastic rocks are intimately associated. Dr. Selwyn may be considered one of the first of American geologists who distinctly apprehended and stated the eruptive nature of these rocks. They had been regarded as "altered Quebec" rocks, and as such Sir William Logan extended the Quebec group over them, and elsewhere included a great range of basic eruptives. On his great Canadian geological map, 1866, the Quebec group extends along the northwestern side of lake Superior. It embraces what is now known as the Animikie and Keweenawan. But Selwyn effected a great revolution in this classification. He rejected the Quebec group entirely, and separated the rocks that had been so mapped and described into several systems. Unlike Logan, he saw also the alliance

---

* Bull. Dept. Geol. Univ. Cal., vol. I, no. 8.

†Geological Survey of Canada, Rep. of Prog., 1877-78. Report A, pp. 3-15.

between the eruptives north from the Vermont boundary and those of the upper Laurentian and the Norian. The Grenville series, with its crystalline limestones and anorthosytes, "the supposed upper Laurentian or Norian" and the "altered Quebec group" he correctly describes as of the same age as the "typical or original Huronian" or "probably Lower Cambrian." In the introduction to his paper he intimates that the stratigraphy of the Laurentian rocks on the north side of the St. Lawrence valley "has a close connection" with that of the Quebec group. At that time that was a bold position to take, but many new facts that have been brought to light since, bearing on this problem, have gone toward a demonstration of its correctness. It matters not that the term Huronian has been largely extended since and geographically has rarely been applied to these rocks by the Canadian survey, even under the sanction of Dr. Selwyn, nor that the Lower Cambrian age of the Norian and of its crystalline clastic rocks has not been admitted by him,* because that extension of the Huronian has been an accidental after-thought and is not in keeping with the original descriptions, and because the Lower Cambrian age of the Norian has been accepted by an increasing number of later geologists who have examined their field relations.

Dr. Selwyn describes two "groups" of rocks running northward from the Vermont boundary, one of which he calls the volcanic group ("group 2"), and one of crystalline schists ("group 3"). In the light of present knowledge these seem to be identifiable with similar groups which occur in the Lake Superior region, viz: the Keweenawan and the Animikie or original Huronian. His "group 2" is thus described:†

This group embraces a great variety of crystalline, sub-crystalline and altered rocks, coarse, thick-bedded, feldspathic, chloritic, epidotic and quartzose sandstones, red, grey and greenish siliceous slates and argillites, great masses of dioritic, epidotic and serpentinous breccias and agglomerates, diorites, dolerites and amygdaloids, holding copper ore; serpentines, felsites and some fine-grained granitic and gneissic rocks also crystalline dolomites and calcites. Much of the division on the southeastern side of the axis, is locally made up of altered volcanic products, both intrusive and interstratified, the latter being clearly of con temporaneous origin with the associated sandstones and slates.

*Science, vol. I, p. 11, 1883.
†Geol. Sur. Can., Rep. for 1877-1878, p. A5.

The relations of this assemblage of rocks with those of group 3 have not been clearly ascertained and he suggests that the two groups may be connected by gradual transition without non-conformity, and especially as the great development of volcanics seems at one place to be near the base of group 2, and at another to be at or near the summit of group 3. He states that they must be intimately related. His group 3 is thus described in general terms.

The rocks composing it are chiefly slaty and schistose and embrace various chloritic, micaceous, siliceous and magnesian strata with copper ores, also imperfect gneisses, white and grey crystalline micaceous dolomites and magnesian limestones. They constitute the main anticlinal axis of the region, which axis may be traced from Sutton mountain, east of lake Memphremagog, on a gently curving line northeastward to the counties of Montmagny and L'Ilet—a distance of 150 miles.

The copper and copper ores of the region he considers to be divisible into two classes, under conditions almost if not quite as distinct as they are in the Lake Superior region. One class belongs to the crystalline schist group, and occurs in veins and lodes coincident with the stratification, generally ores, and the second class occurs in intimate association with eruptives, such as amygdaloids and eruptive agglomerates. He finally concludes:

There seem to be no good grounds for assigning either an age or an origin to the cupriferous diorites, dolerites and amygdaloids of the eastern townships different from that of the almost identical rocks of lake Superior.

The Hastings series he briefly alludes to, showing its parallelism with the lower portion of the Grenville series. Indeed the Hastings series bears many characters, not alone in its structural relations with the Grenville, but in its composition, that make it comparable with the schists of the "group 3" at Sutton mountain, while the Grenville series, in its stratigraphic sequence and its mineral composition, may as easily be compared with group 2. They both belong to the upper Laurentian, one being apparently the modified sediments of a great series of fragmentals and the other a later mass of crystalline eruptives carrying metamorphosed and isolated parts of the fragmental series.

Since the work of Selwyn probably that of Ells is the most

important, at least in its structural bearings.* In his first report on the eastern townships he gives a very full description of them. The sedimentary beds are described thus:

> These rocks present a considerable variety of characters, embracing slates of various colors, purple, black, green and gray, along with sandstones, often so highly quartzose as to form in places a hard quartzyte, quartziferous schists and conglomerates. The sandy and quartzose beds are very similar to some of the so-called Sillery sandstones of the Quebec group, and the few indistinct fossils that have been found in similar slates elsewhere are considered by Prof. Lapworth to be of Cambrian age, while other parts of the series may perhaps represent some of the lowest members of the same system.

The Sutton Mountain range, composed of gneissic mica schists, is the anticlinal on the flanks of which these volcanic rocks lie apparently non-conformably. They are at the same time non-conformable below the Silurian, i. e. the "Cambro-Silurian." A great variety of volcanic rocks belong to this system, as already noted,† including dioryte, dioritic agglomerate and breccia, dioritic schist, diabase and serpentine. "These form a well defined. elevated belt, extending from near the Vermont boundary, west of Memphremagog lake, with some interruptions for nearly or quite 150 miles." (Ells, Report for 1887, p. 28J.) If these be not a part of the Archean fundamental complex, comparable with the greenstones of Minnesota, they are a remarkable volcanic group of Taconic age, and can perhaps be compared with that series of Taconic volcanics lately discovered by Van Hise in the Penokee-Gogebic iron-bearing series of Wisconsin and Michigan.‡

From the region of the Taconic in the "eastern townships" and the Norian of the Ottawa valley, let the attention of the reader be given to that of the original Huronian. The rocks of this famous region, which are now well known to be the equivalent in the main of the Animikie rocks of the west side of lake Superior, consist of a series of slates, fine-grained graywackes, quartzytes and marble, interstratified and cut by irregular masses of basic irruptives. Structurally, strati-

---

*Report on the geology of a portion of the eastern townships. Report of Progress, Can. Geol. Sur., New Series, vol. II, 1887.

Second report on the geology of a portion of the province of Quebec. Report of Progress, Geol. Sur. Can., New Series., vol. III, 1888.

†AMERICAN GEOLOGIST, March , 1895.

‡Bull. Geol. Soc. Am., vol. IV, p. 435.

graphically and petrographically these are essentially equivalent to the series which have already been mentioned as Grenville and Hastings, but less crystalline. The conglomeratic non-conformity upon the lower Laurentian, the rather slight crystallization, the association with characteristic basic and acid eruptives, the superjacent non-conformable Upper Cambrian, are points which show their agreement on the one hand with the Norian of the Ottawa valley and of the Adirondacks, and on the other with that of the west side of lake Superior. There is no possible other inference without a violent traverse of the most natural and manifest conclusion of geological judgment. The details of the comparison need not be entered upon here.

Reference may further be made to various places in the northern part of Canada, where, in the opinion of Dr. G. M. Dawson, the Lower Cambrian eruptives exist. The descriptions of Sir John Richardson are quoted by him in his "Notes to accompany a geological map of the northern portion of Canada east of the Rocky mountains."* These rocks occur along the Coppermine river and in the Copper mountains.

It is further quite evident that in the extensive area colored as Cambrian on the Arctic coast, in the vicinity of the Coppermine river, the rocks are analogous in character to those of the Keweenaw or Animikie of the Lake Superior region, and probably represent both groups of that great copper-bearing series. The mere occurrence of native copper in considerable quantities on the Coppermine, in association with prehnite and other minerals resembling those which accompany it on lake Superior, gives a *prima facie* probability to this correlation, which is borne out by a more careful study of Sir J. Richardson's accurate notes, and was recognized by Richardson himself, who had examined both regions. (P. 8R.)

To this age also he refers rocks upon the Great Slave lake, and on the route from Great Slave lake to Great Fish river, also the great volcanic series of Dr. R. Bell, the Manitounock group, of the east coast of Hudson bay, and the red sandstones of his "intermediate group."

Throughout the whole of the vast northern part of the continent this characteristic Cambrian formation, composed largely of volcanic rocks, apparently occupies the same unconformable position with regard to the underlying Laurentian and Huronian systems. Its present remnants serve to indicate the position of some of the earliest geological basins, which, from the attitude of the rocks, appear to have under-

*Geol. Sur. Can., vol. II, New Series, Rep. R, 1887.

gone comparatively little subsequent disturbance. Its extent entitles it to be recognized as one of the most important geological features of North America.

There is but one other Canadian locality where the Taconic eruptives may be identified. It is the region of Thunder bay on the northwest coast of lake Superior. By the Canadian geologists the rocks of the Animikie have been referred consistently and uniformly to the age of the Lower Cambrian, but they fail, for the most part, to apprehend their identity with the rocks of the original Huronian—a correlation to which American geology is first of all indebted to the late R. D. Irving. The Animikie rocks extend into Minnesota and some of their structural and petrographic characters as they there appear will be mentioned when we come to consider especially the Lake Superior basin as a structural unit. At the present it is only necessary to refer to some of the descriptions that have been published. Logan put them in the "lower volcanic group" of the Copper-bearing series, and later made them of "Quebec" age. Selwyn distinctly affirmed their Cambrian age. Irving showed that they are the horizontal and unmodified strata of the original Huronian, which, until the confusion and misconception introduced by the extension of that term downward to the Archean gneisses, had been classed as Cambrian by Canadian and English geologists.

At the bottom is a great mass of chert or flint, replaced sometimes by an erosion-conglomerate, very siliceous, made up of pebbles from the underlying gneisses and schists. Limestone appears in association with the basal beds, but this feature is not greatly developed. In this limestone are masses of chert usually somewhat angular. Above this rises a great thickness of black slates, siliceous gray slates, very fine graywackes and quartzytes. These beds are nearly horizontal, and, according to Irving, they are non-conformably overlain by the sandstones and marls of the lower Keweenawan in the vicinity of Black bay. That, however, which here is to be specially noted is their association with eruptives. These have been described by Bell, Ingall and Lawson,* and by others.

*Robert Bell, Geol. Sur. Canada, Rep. for 1869, pp. 313-363; ditto, 1872, pp. 87-93.
E. D. Ingall, Geol. Sur. Can., Rep. for 1887-88, part 2. Report H, pp. 1-131.
A. C. Lawson, Geol. Sur. Minnesota. Bulletin 8, The laccolitic sills [illegible] northwest coast of lake Superior, 1893.

Bell considered the eruptive sills that appear interstratified with the slates as surface trap flows, cotemporary with the sedimentary depositions, and the whole of Permian or Triassic age. Sir W. E. Logan, however, in a note in the same volume, shows satisfactorily that these beds cannot be other than as usually believed, i. e.,Cambrian. Mr. E. D. Ingall called attention to the intrusive character of some of these diabase sheets, and Lawson affirms as a general proposition that there are no contemporaneous volcanic rocks in the Animikie group, but that all the sheets are of the nature of laccolitic sills. So far as the region examined by Lawson is concerned it may be accepted as a correct statement of the relations of these igneous rocks. But when it is remembered that these laccolites of the Thunder Bay district are both numerous and thick, and that they can be only the offshoots from some central area, far or near, where this intrusion must have had its source and greatest activity, it is very reasonable to expect both greater disturbances of the same strata and traces of volcanic débris in the rocks of the age at which the disturbance took place. That the eruptives of the northwest coast of lake Superior cannot all be assigned to a single epoch of disturbance is made evident by the researches of Lawson. That some were as early as the lower part of the Animikie there is still reason to believe. This will appear in a subsequent paper.

There are Taconic sedimentary rocks much further west, even on the eastern slopes of the Rocky mountains, as first brought to light by Dr. Rominger.* The same fact had been discovered earlier, though apparently not yet published, by Mr. R. G. McConnell, of the Canadian Geological Survey. There is a vast thickness here of Taconic slates and quartzytes, *Olenellus* having been found at an estimated thickness of 8,000 feet above the base, but no igneous rocks have been reported.

If a rapid glance now be given at the facts recited concerning the existence of Taconic eruptives in Canadian territory, it becomes apparent that a similar and cotemporary history

*CARL ROMINGER, Description of Primordial fossils from Mt. Stephen, N. W. Territory of Canada, Proc. Acad. Nat. Sci. Phila., 1887. Reviewed by Mr. C. D. WALCOTT, Am. Jour. Sci., Sept., 1888. See also ROMINGER, AM. GEOLOGIST, vol. II, p. 356, 1888; R. G. MCCONNELL, AM. GEOLOGIST, vol. III, p. 22, 1889; Rep. Prog. Can. Geol. Sur., 1886, Report D [1887].

was experienced over the northern half of North America in Lower Cambrian time. The Archean floor, which, whatever its origin, had been flexed and broken, cemented, bent, eroded, and again flexed and eroded, producing a congeries of inextricable confusion, and almost baffling all efforts at classification, was widely submerged by the early Taconic ocean. This ocean crept upon the primitive continent from the north and east. Perhaps it covered it entirely. But we know not what lies upon the Archean floor in the interior of the continent where later rocks have been deposited and still exist. That area is nearly as closely sealed against the geologist as is the Archean floor beneath the Atlantic. However, so far as later sediments do not now conceal it, the remarkable Taconic-Archean contact seems to have been found from the Arctic sea to the region of the Laurentides north of lake Superior, and from Newfoundland to Minnesota and to the Rocky mountains. The pre-Taconic floor has also been detected at several points in states further south. Not only was this pre-Taconic floor buried under the basal Taconic beds presumably throughout Canadian territory from the Atlantic coast to the Rocky mountains, and in New York and New England, but in many places the Taconic strata seem to have been cotemporaneously disturbed by volcanic ejections, and to have been intruded at a later date by great volumes of anorthosyte and allied basic eruptives.

[PALÆONTOLOGICAL NOTES FROM BUCHTEL COLLEGE. No. 10.]

RECENT CONTRIBUTIONS TO OUR KNOWLEDGE OF THE CLADODONT SHARKS.

By E. W. CLAYPOLE. Akron, Ohio.

Although the name *Cladodus* has long figured in the literature of palæontology, yet it has been nothing more than a name so far as the animal which it represented was concerned. Applied to detached teeth it gave us no knowledge at all concerning their wearers. We knew the peculiar three- or five-pointed form of the little, usually black, objects in the stone, but all that we could affirm concerning the fish was drawn by analogy from the existing sharks. But the recent discovery

of numerous specimens of these fossils in the Cleveland shale of northern Ohio enables us to rearrange what we did know, and to add some new details which confirm and modify previous opinion on the subject. To point out a few of these is the purpose of the present note.

1. SPINES.—When Prof. Traquair wrote his article for the Geological Magazine in 1888, the evidence for the presence or absence of spines on the cladodonts was insufficient for decision. So doubtful did this feature then appear to him that he even ventured to suggest the identity of *Ctenacanthus* with *Cladodus*. "The thought has struck me" he says, "is it possible that this undoubted *Cladodus* may represent the dentition of *Ctenacanthus costellatus*, the unique specimen of which, with the spines *in situ*, occurred in the same beds? It will be recollected that the only tooth visible in the specimen of *Ct. costellatus* was an imperfect one, but its median cusp was smooth. If there is any connection here the specimen of *Ct. costellatus* must have been a young individual, as these teeth indicate a fish of much smaller size." "This brings up once more the question of the correlation of *Cladodus* and *Ctenacanthus*, a question which, I must admit, is still involved in great obscurity. When I wrote my description of *Ctenacanthus costellatus* I was inclined to believe that *Ctenacanthus* and *Cladodus* represented the spines and teeth of the same genus, and that the genus itself was hybodont."

Again Prof. Traquair writes regarding *Chlamydoselachus*: "I cannot, without farther evidence, accept Mr. Garman's very confident assertion that *Chlamydoselachus* is a cladodont, leading, as it does, to the inference that *Cladodus* had no dorsal spines." Again: "No spine is seen in the East Kilbride specimen, but as the body is absent, spines may have been borne by the fish when complete."

Summing up, the professor writes: "*Ctenacanthus hybodoides* has nothing to do with *Cladodus*, and as regards the other species I rather think that if we knew the creatures to which they belonged they would turn out to represent several types, possibly very different from each other."

We have in these passages the record of the various changes of opinion which the gradually increasing light led professor Traquair to adopt regarding this group of fossil fishes, and it

is a proof of great skill and sagacity that he succeeded, with the meager evidence afforded by so imperfect a specimen as must be that from East Kilbride, in constantly approximating to the truth at every step. This is evident when we take into consideration the new fossils of the Cleveland shale of Ohio.

The several species which have already been described and others still awaiting examination leave no standing ground for the theory that *Cladodus* and *Ctenacanthus* were identical or even nearly related to one another. Setting aside the weighty, but not determinative fact, that with one or two very doubtful exceptions, no specimens of *Ctenacanthus* have ever been found in the Cleveland shale in northern Ohio, we have the decisive evidence of the fossils themselves, for among all the numerous specimens of *Cladodus* that have come to light from this stratum of the upper Devonian, not a single one shows any trace of a spine on any of its fins. Several of these fossils are so well displayed and so well preserved that had fin-spines existed they could hardly have escaped detection. The pectoral and caudal fins are very coarsely rayed (the former anteriorly only), but the ventrals are comparatively soft. Evidence regarding the dorsal or dorsals is somewhat less clear, but scarcely less certain. in consequence of the position of the fishes.

The evidence of the fossils may therefore be regarded as conclusive in favor of the opinion that *Cladodus* was a genus of spineless sharks, at least so far as concerns the North American upper Devonian forms, and the specimen of Dr. Traquair bears testimony in the same direction for those of the Carboniferous strata. All connection with the spiny sharks is consequently cut off, and it remains to discover the wearers of the formidable weapons so abundant in certain strata.

2. Teeth.—If the evidence of these Ohio fossils is thus conclusive regarding the spines of the cladodonts, that concerning their teeth is not less valuable, if less assuring. Indeed, some of it is decidedly unsettling of previous opinion, for it is more than likely that one result of the study of these fossils will be to destroy all confidence in the species of *Cladodus* already based on the form of the teeth. Thus far, all the names given rest on this basis alone. The utter uncer-

tainty and comparative uselessness of such definitions will at once appear when, as in the case of a still undescribed specimen in Dr. Clark's collection, three forms of tooth are seen in the same mouth, of which two only are truly cladodont. Obviously no description resting solely on the form of a tooth can be maintained for any other object than for that tooth itself. As names for the fishes that carried the teeth they must evidently be very uncertain unless we can determine the fish to which each belonged, and this, in the light of the above fact, will never be in all cases possible. And even where it can be done it will be more philosophical to refer the tooth to the fish than the fish to the tooth.

Cladodent teeth are very abundant especially in Carboniferous strata such as the Lower Carboniferous limestone of Illinois and Indiana and the Mountain limestone of England, but, with the exception of the specimen described by Dr. Traquair and perhaps one or two others, all very imperfect, we had until the Cleveland fossils came to light no knowledge of the fishes themselves.

3. Fins.—These present a few points deserving of note. In the first place the pectoral fins exhibit very coarse rays in the anterior portion and as far as the middle, behind which point they become finer to the posterior extremity. There is a distinct membranous border crossed by numerous excessively fine raylets or trichinosts. The number of rays seldom varies much from twenty and there is little forking, except in the smaller ones, though intermediate, secondary and even tertiary rays appear toward the margin, either in consequence of a duplication through crowding or the persistence of a second and third row whose bases have been suppressed for want of room. It is very difficult in the specimens that I have examined to see any trace of the "archipterygial" form of fin, as defined by Gegenbaur. The fin presents a decidedly icthyopterygial form, at least outside of the body, the rays extending continuously from the body line to the tip. Whatever structures existed within the body as a pectoral girdle are too indistinct in the crushed condition of the fossil to be positively identified. Possibly other specimens may exhibit these parts more clearly in the future, but the interpretration of the con-

fused and broken skeleton as now known would be too speculative to afford a sure basis for inferences.

But perhaps the most interesting feature, especially in a theoretical sense, which is presented by these Devonian sharks, is a peculiar flap or fold of the skin which projects horizontally in front of the caudal fin and makes a most remarkable showing when the hinder part of the fish is preserved. The caudal fin is then scarcely seen, showing merely a sharp edge ending in a point. But the wide expansion of the flap just in front of it gives the appearance of a widening of the body that in a fish is, to say the least, extraordinary. Such a structure is not perhaps quite unexampled among recent fishes, but in no case, so far as I know, can anything corresponding to the one here described be found. The flap is entirely membranous and shows no trace of fin-rays. Yet it was rather solid and has left at least as clear an impression on the stone as has the membranous margin of the pectoral fins. It can be looked on as a third pair of paired fins set back near the posterior extremity of the fish in a post-ventral position. They evidently may have been of great service to the fish in giving a powerful horizontal leverage against the water and so enabling it to strike in an upward or downward direction. They may thus have served, in a less degree, the same purpose as the flukes of the whale, enabling these sharks to ascend or to descend in the water with great ease and rapidity.

These fins are attached to the sides of the animal by broad bases and form triangular projections whose appearance, when seen from below, may be likened to that of a pointed shovel. So far as known it seems probable that this appendage was common to all the species of *Cladodus.*

The interest of this peculiar feature in connection with theoretical views that are prevalent regarding the origin of the paired fins is obvious. The fact of the evolution of the azygous fins from the primeval and embryonic continuous marginal membrane, seen even now in the bowfin (*Amia calva*) and other fishes and in the tadpoles, may be considered an established doctrine, however difficult it may at present be to account for the gradual concentration of the fin development at a few points in most of our recent fishes. But the parallel doctrine of the evolution of the paired fins—the archetypes

of the four limbs of the vertebrata—from a supposed similar but horizontal membranous flap, does not at present rest on an equally secure basis. If it is true, then changes have occurred in these far more profound than any of which we have evidence in the former organs. But the greater amount of supposition required in the case of a lateral fin-fold is of course an obstacle not to be lightly estimated. And from this point of view it is therefore exceedingly interesting to find what may prove to be an ancient relic of such a primeval lateral fin in these Devonian sharks. If the archetypal fold extended from the pectorals to the ventrals it may as well have extended further to the place of these post-ventrals, if we may so call them, and then have run into the caudal fin and so met and fused with the dorsal-ventral fold, encompassing the body horizontally as the other encompassed it vertically.

It may be rank heterodoxy to even hint at the existence of a third pair of limbs in a vertebrate. But on the above view there is nothing monstrous or incompatible about it. It is anomalous judged from the existing creation, but so was the pineal eye thought to be when first mooted. Yet it is now an accepted fact in anatomy of which, however, few traces have survived to the present. Possibly further discoveries in Paleontology may bring to light other indications of the curious organs here described. Whether the solution above suggested be the true one or not, it is certain that some Devonian sharks possessed these singular appendages whose origin must in some way be accounted for.

CAMPTONITE DIKES NEAR DANBYBOROUGH, VT.

By VERNON F. MARSTERS, Indiana University, Bloomington, Ind.

Some twenty-five miles south of Rutland, Vermont, on the Bennington & Rutland railroad, is situated the little village of Danbyborough. The town rests in a deep, narrow valley or gorge-like depression, drained by an extension of the Otter creek or river. This stream runs north through Rutland, Pitsford and Middlebury and finally empties into lake Champlain at a point nearly due west of Ferrisburgh. On the west side of the valley, in the region of Danbyborough, the

rocks are composed of white crystalline limestone, and further west they consist of calcareous and talcose schists. The limestones in the early reports on the geology of Vermont are designated as the Eolian limestones.

On the western flank of the valley in a southwesterly direction from the village were found two abandoned quarries. These openings are probably the *Symington* or *Fisk* quarries mentioned in one of Hitchcock's early reports as being intersected by dikes.

In the upper quarry were found two dikes cutting the limestones in a direction approaching N. 47° E. and N. 30° E., about one thousand feet apart and with a thickness of one and five feet respectively.

The dikes are characterized by a hypidiomorphic structure, dark gray in color when fresh, but rusty brown in the weathered outcrop. Although the greater part of the rock is very fine grained, minute lath-shaped crystals can be seen in the hand specimen without the aid of a lens. Scattered through the rock are numerous minute pockets or cavities filled with a white mineral substance. In some instances these prove to be calcite, in other (as noted in the thin sections) they consist of minute aggregations of feldspar crystals.

Microscopic examination proves these rocks to be made up of idiomorphic hornblende of the basaltic type, augite in two generations, small amounts of plagioclase, and more or less glass in the interstices of the ground mass. Although this mineral mixture is regarded as a Camptonite, it nevertheless differs in some respects from the Campton Falls dike, which is regarded as the type. The "Danby" occurrence differs from the type in exhibiting but *one* generation of hornblende. Not a single large phenocryst of hornblende has been found in the several sections made from each dike. The form present is lath-shaped with ragged terminations, and is identical with the hornblende of the *second generation*, as noted in the Campton dikes. The pleochroism, ranging from light yellow to deep reddish brown, is unusually strong. Numerous cross-sections were noted in which prismatic and pinacoidal faces were easily recognized and in some instances the crystals were sufficiently large to show clearly the characteristic prismatic cleavage.

Augite occurs in *two* generations, but by far the larger portion is allotriomorphic. It is not so prominent as the hornblende. Very few well-developed augite phenocrysts appear. Such as are present are usually light yellow in color and generally show slight pleochroism. In dike No. 1 the allotriomorphic augite is decomposed to such an extent that only the central portions remain at all fresh. A few minute individuals of green pyroxene were found closely associated with the augite. Plagioclase is not very abundant. In dike No. 2 its occurrence is rather unique. It is not uniformly distributed through the rock, but is apparently developed in tufts or aggregations of individuals. Such an arrangement presents a patch-like appearance in the thin sections and in the hand-specimens resembles porphyritic structure. Some of these white inclusions were found to be pockets of calcite. The fresh plagioclase contains exceedingly minute acicular inclusions, many of which seem to be arranged in parallel series. They are regarded as apatite. The plagioclase has also suffered considerable mechanical deformation. Many of the larger individuals are bent and twisted to such an extent in some cases as to cause fracture. The groundmass consists of an opaque gray substance, resembling decomposed feldspar very closely. Considerable glass was found in the interstices of the feldspathic portion of the various sections. Comparing this rock with the original camptonite of Hawes, it should be said that the colored bisilicates form a *larger* portion and the feldspar a correspondingly *smaller* portion of the rock-mass than noted in sections of the type rock.

In conclusion, then, it should be added, that while these dikes are legitimately regarded as camptonites they are somewhat abnormal in the development of the individual constituents, there being but *one* generation of hornblende and *exceedingly few* augite phenocrysts, fully nine-tenths of the pyroxene being allotriomorphic.

This is but one of a number of occurrences of camptonite dikes discovered within the last few years in New England and other states. They were first noted by J. W. Hawes* at

*J. W. Hawes: On a group of dissimilar eruptive rocks from Campton, N. H. Am. Jour. Sci., 3, vol. XVII, p. 14, 1879.

Campton Falls, N. H., and lately by Prof. J. F. Kemp* at Kennebunkport, Me. Dr. B. J. Harrington,† of the Canadian Geological Survey, has found similar dikes near Montreal. Others have been described from a locality near Whitehall, N. Y.,‡ and Proctor, Vt., as well as from the shores of lake Champlain, by Prof. J. F. Kemp and the present writer.§ They are also known to occur on the shores of other lakes in northern Vermont and southern Quebec, especially lake Memphremagog, and at Sherbroke, Quebec, a few miles north of this lake.

AURIFEROUS GRAVELS OF THE SIERRA NEVADA.‖

By H. W. TURNER, Washington, D. C.

As may be seen by referring to a paper by Ross E. Browne on "The Ancient River Beds of the Forest Hill Divide,"¶ and another by the writer on "The Rocks of the Sierra Nevada"** the Neocene Auriferous gravels of the Sierra Nevada can be divided into two main groups: those of the first period, composed chiefly of white quartz pebbles and light colored clays and sands, with minor lava flows of rhyolite; and those of the second period, called by Browne the "volcanic period," formed during the time of the "volcanic cement" (andesite-tuff) flows. The former gravels are free from volcanic pebbles, the latter often contain them in abundance. The larger mass of the Auriferous gravels belong to the first period. That an era of erosion occurred between the deposition of the gravels of the first period and those of the second period is abundantly proven, and it therefore follows that the fossil remains found in the two classes of deposits should indicate some difference

---

*J. F. Kemp: Trap dikes near Kennebunkport, Me. AMERICAN GEOLOGIST, vol. v, p. 127, March, 1890.

†Dr. B.J. Harrington: Can. Geol. Survey, 1877-78, p. 439.

‡J. F. Kemp and Vernon F. Marsters: On certain camptonite dikes near Whitehall, Washington Co., N. Y.

§. F. Kemp and V. F. Marsters: The trap dikes of lake Champlain. U. S. Geol. Survey, Bull. 107.

‖Published by permission of the Director of the U. S. Geological Survey.

¶Tenth Ann. Rep. State Mineralogist of California, pp. 435-465. Browne's third period includes the Pleistocene gravels.

**Fourteenth Ann. Rep. U. S. Geological Survey, p. 465.

in age. Up to the present time however, no attempt has been made to discuss the remains from different localities separately.

FIRST PERIOD.

The older Auriferous gravels, or those of Browne's first period, have furnished nearly all the plant-remains that have been studied. Thus the leaves from the gravels at Chalk bluffs* studied by Lesquereux, belong to the older gravels, as does also the collection from Independence Hill, made by Dr. Cooper Curtice, and now in the U. S. National Museum.

The following localities, where the older gravels are well exposed, have not thus far furnished many fossil plants, but should be carefully examined: Gibsonville, Howland Flat, Poverty Hill, Scales, and Brandy City, in Sierra county; Laporte and vicinity in Plumas county; near Placerville in Eldorado county; the channel south of Oleta in Amador county; and the Chili Gulch channel in Calaveras county. The fossil leaves from these older gravels were thought by Lesquereux to indicate a Pliocene age, but later investigations by Ward and Knowlton indicate that the age may be Miocene.

Prof. Knowlton says: † "There can be no doubt but that the plants from Ellensburg (Washington) are similar in age to the Auriferous gravels and the John Day valley. The John Day valley deposit has always been called Miocene. The Auriferous gravels, on the other hand, were regarded by Lesquereux and others as Pliocene, but a recent examination of that flora based on extensive collections from Independence Hill, Placer county, California, seems to indicate that they also are probably upper Miocene in age."

The following is a list of the plants determined by Prof. Knowlton from the Ellensburg locality:

Salix varians Gopp.
Populus glandulifera Heer.
Populus russelli, sp. nov.
Alnus sp. ?
Ulmus californica Lx.
Ulmus pseudo-fulva Lx.
Platanus dissecta Lx.
Platanus aceroides ? (Gopp.) Heer.
Paliurus colombi Heer.
Magnolia lanceolata Lx.

*Memoirs Mus. Comp. Zool., vol. VI. part II.
†Bull. 108, U. S. Geological Survey, p. 104.

Mr. J. S. Diller has lately received from Prof. Thomas Condon, of Oregon, some fossil teeth of a horse-like animal, and has kindly allowed the writer to insert a note concerning them. These remains came from the Ellensburg plant beds and hence give additional evidence as to their age. The teeth were examined by professors Cope and Lucas, who report that they are the "right size and pattern for either *Hippotherium speciosum* or *H. isosensum*. The former has not been found to the northwest and the latter is said to be the commoner species. Both are upper Miocene."

The Ione formation, deposited synchronously with the older Auriferous gravels above described, also contains fossil plants and other remains, and these can therefore be brought in evidence as to the age of the gravels. The deposits underlying the Oroville table mountain belong to this formation, and contain leaves at the Spring Valley hydraulic mine, and also at the abandoned Miocene hydraulic mine in Morris ravine.

The leaves collected at the former locality by Diller* were considered by Prof. Ward to be Miocene or older in age. The leaves collected by the writer at the Miocene mine are mostly of deciduous trees and are not well preserved. Mr. W. Lindgren has discovered some white fine grained beds on Dry slough (Smartsville atlas sheet) about five miles northeast of Wheatland, which contain fossil leaves, and the locality is a promising one for the future collector. The Ione formation is best exposed in the area of the Jackson sheet, particularly above Ione, but although a careful search has been made by the writer at many points, no fossil leaves have thus far been found in this region that can be determined specifically. In Coal mine No. 3, near Ione, leaves which Prof. Knowlton considered to be probably those of a *Sequoia* were obtained. Mr. Lindgren obtained fossil shells referred by Stearns and Dall to the Miocene, from beds in the Marysville buttes, and these beds are thought by Lindgren to belong to the Ione formation.

There is still other evidence of the Miocene age of the older Auriferous gravels. Underlying the tuffs of the Lassen Peak region are a series of light colored lake beds that have been

*Bulletin 33, U. S. Geological Survey, p. 16.

studied by Diller* and are thought by him to be synchronous with the Ione formation. At several points in this fresh-water deposit he obtained fossil leaves, and these Prof. Lesquereux determined as of Miocene and probably of upper Miocene age.

Prof. F. H. Knowlton in a recent letter expresses the opinion that the flora of the Auriferous gravels have upper Miocene affinities. He writes: "Out of 55 species found in Alaska, and belonging with hardly any doubt to the Eocene, no less than 17 are common to the Auriferous gravels and allied formations of California, which is sufficient to grade the beds down at least to the Miocene. I am also finding a number of plants from the Yellowstone National park that are common to California. The park flora is in turn clearly allied to the Fort Union (Eocene), which also tends to bring down the Auriferous gravels flora. The only thing against the Miocene age of the California flora is its evident close relation to the living, and even this might be modified by a re-study of the material."

Prof. Knowlton's opinion is based on a study of leaves from many different localities, but chiefly from the gravels of the first period.

INTERMEDIATE PERIOD.

The plant beds in Mohawk valley and at the Monte Cristo mine in Spanish Peak† are overlain by andesitic breccia. They pretty certainly represent formations later in age than the white quartz gravels and associated deposits above described, but it is not certain that they represent the distinctly later second period of the "volcanic cement" flows. The same is true of the deposits under the Tuolumne table mountain, studied by Lesquereux, which have been covered by a flow of basalt, and of the Dodson mine gravel from which the fossil wood *Araucarioxylon* was obtained. The latter deposit is also under basalt, the kind elsewhere called the older basalt, which is older than the "volcanic cement" (andesite-tuff) flows, but probably younger than the rhyolite flows that are associated with the earlier white quartz gravels.

The pebbles of the gravel deposits of this intermediate

*Eighth Ann. Rept. U. S. Geological Survey, pp. 413-422; and Journal of Geology, vol. II, pp. 32-54.

†Fourteenth Ann. Rept. U. S. Geological Survey, pp. 466-67.

period are chiefly of the pre-Cretaceous sedimentary and igneous rocks and are usually dark in color; such gravel is frequently called "bull or bastard gravel" by the miners, as it is often less auriferous than the white quartz gravel, and is not always of economic importance. It should be noted that Lesquereux made no distinction in age between the leaves from under the Tuolumne table mountain and those from the probably older gravels at Chalk bluffs.

Second Period.

Plant remains that are without doubt from materials of the second period are not abundant. Those collected by the writer consist chiefly of fossil wood from the "volcanic cement" (andesite-tuff) itself. Some of these specimens have been examined by Prof. Knowlton, who identified *Cupressinoxylon* and *Pityoxylon*. It should be noted that the materials of the second period are largely coarse gravels with few layers of fine sediment calculated to preserve the leaves and stems of plants. The gravels of the Dogtown mine, 3 miles north of Altaville (Jackson folio), and those south of San Andreas belong to the second period as do also the Neocene shore gravels of the Jackson folio.

In regard to the vertebrate remains reported on so fully by Prof. Whitney, it may be noted that many of those bones came from deposits which are known to the writer to be later in age than those furnishing the plants. This is certainly true of some of the localities where mastodon remains have been found. Thus the gravels at Horse Shoe bend* are Pleistocene in age, while other localities are probably Miocene.

The following quotation from Dr. Dall† is significant on this point: "Cope has pointed out that among the vertebrates from these gravels one (*Elotherium*) is not Pliocene nor even upper Miocene, but belongs to the Eocene or lowest Miocene (White River group), while *Mastodon obscurus* is upper Miocene."

The *Elotherium* referred to by Cope was found at Douglass Flat (Big Trees atlas sheet) in Calaveras county, but the material from which it came is not definitely described. The only specimen of *Mastodon obscurus* reported by Whitney

*Auriferous Gravels, p. 261.

†Bulletin No. 84, U. S. Geological Survey, p. 222.

from the Sierra Nevada was found by Dr. Lorenzo Yates on Dry creek, Stanislaus county, but in this case also the kind of material is not indicated, so that without fuller information these specimens are not of much value for determining the age of the Auriferous gravels. A locality that promises much was discovered by C. D. Voy* "on a nameless dry creek tributary to Bear creek, in Merced† county, near the line of Mariposa, about six miles southwest of Indian Gulch. The rocks at this place consist of a coarse, friable, light colored volcanic ash, which envelopes a large quantity of bones, and also contains the remains of vegetation, and especially the casts of some small fruit or seed vessel, the relations of which have not been made out."

In a paper on the geology of mount Diablo‡ the writer called attention to the Kirker pass fossil locality where there are leaf-beds with fossil wood, associated with beds containing marine shells which have been referred to the Pliocene. Andesite-tuffs form part of the same series. A large collection should be made of all of these fossils, for here we have in the marine shells a check on the value of plant remains for the determination of the Tertiary deposits of California.

It is suggested in the bulletin on mount Diablo that the beds at Corral Hollow are of the same age as those at Kirker pass, and inasmuch as the marine shells at the latter locality are pretty certainly Pliocene, it was believed that the Corral Hollow series must also be Pliocene. The correlation of the beds at the two localities was made on the basis of similar volcanic deposits (andesitic tuff and conglomerate) occurring at both places. On referring to his note-book the writer finds a section representing the Corral Hollow plant beds, which are composed of fine whitish material, resting on a series containing fossil oysters, and overlain with apparent conformity by the volcanic conglomerate beds. Another visit to the locality will therefore be necessary to determine whether or not the plant beds are older than the andesitic materials.

The andesitic tuffs at Kirker pass, however, also overlie the

*Auriferous Gravels, Whitney, p. 247 248.

†This part of Merced county is now called Madera county.

‡Bull. Geol. Soc. Am., vol. II, pp. 396-397.

leaf beds, but the writer's recollection is that in the latter case the series is, without doubt, conformable.

The following partial analysis of the fine white material containing the fossil leaves at Corral Hollow was made by Messrs. Steiger and Stokes, of the U. S. Geological Survey. The analysis does not appear to suggest with any certainty the nature and source of the material, but is given here in order to have it on record:

No. 449 Sierra Nevada Collection.

$Si\ O_2$	63.07	$P_2\ O_5$	.24
$Al_2\ O_3$	17.02	$K_2\ O$	1.53
$Fe_2\ O_3$	3.96	$Na_2\ O$	3.83
$Fee\ O_2$	1.08		

If considered as fine grained tuff, the material is evidently of andesitic origin.

Another locality where Miocene shells are associated with beds containing fossil wood is on Ocoya creek. A third locality is that already mentioned in the Marysville buttes, where Mr. Lindgren found marine shells in what he considers the Ione formation, and in the same deposits are plant remains.

The following reports by Prof. F. H. Knowlton give information about the fossil flora of the Sierra Nevada additional to that in print:

Report on small collection of Fossil Plants from Poverty Hill and Monte Cristo mine on Spanish Peak, California, submitted by H. W. Turner, January 31, 1895.

Monte Cristo Mine on Spanish Peak.

This material consists of small fragments. None of the leaves are preserved entire, the best consisting of the basal portion only. These leaves all belong to a single species, *Laurus salicifolia* Lx., (Cf. Cret. and Tert. Fl., p. 252, pl. LVIII, figs. 4. 5.) This species was originally described from Corral Hollow and has not before been detected at the Monte Cristo mine, as far as I know.

Poverty Hill.

This material consists of a single piece of matrix on which are fragments of small dicotyledonous leaves. None of them are sufficiently well preserved to admit of satisfactory determination. They seem to belong to the Cupuliferæ, but beyond this it is impossible to venture.

Report on small collection of Fossil Leaves from Volcano Hill, Placer Co., California Sent for examination by H. W. Turner.

This collection consists of about seven small fragments of matrix. A considerable number of fragments of leaves are present, but unfortunately not a single leaf is perfect, and consequently the determinations

are all open to question. With more or less uncertainty the following species have been determined:

Ficus sordida Lx.?
Ficus shastensis Lx.?
Populus zaddachi Heer?
Platanus appendiculata Lx.?
Quercus sp.?
Persea dilleri Lx.?
Plant stems.

Of these *Ficus sordida*, *Populus zaddachi* and *Platanus appendiculata* come from the Auriferous gravels at Chalk bluffs, Nevada county, and *Ficus shastensis* and *Persea dilleri* from the Miocene so-called, of Shasta county. While it is manifestly unsafe to draw very definite conclusions from these meager data, it is probable that the age is Miocene."

The Volcano Hill beds probably belong to the Ione formation and are so represented on Lindgren's Sacramento geologic atlas sheet. The hill is not indicated by name on the map. It is on the ridge north of Rock creek, about three and a half miles north of Folsom, and about one-half mile west of the road to Rocklin. The hill is composed mostly of coarse granitic sandstone with some fine grained layers, in one of which the fossil leaves were collected. The sandstone of the top is irregularly eroded and reddened in places, looking somewhat as if burned, and the hill probably took its name from this peculiarity. The strata are approximately horizontal. The surrounding rock is granite.

The age of the Auriferous gravels has been discussed and the literature bearing on the subject reviewed by Diller in his paper on "Revolution in the topography of the Pacific Coast,"* which is an abstract of a fuller article to appear in the fourteenth annual report of the director of the U. S. Geological Survey. Prof. Diller concludes from the evidence he presents that the Auriferous gravels are largely of Miocene age, and uses this evidence to prove the same age for the old surface of erosion of the Sierra Nevada, which has been preserved intact at many points under the "volcanic cement" flows. That this old surface of erosion was formed during the Auriferous gravel period seems unquestionable. Prof. Diller also considers that an old peneplain at the north end of the Sacramento valley is continuous with and of the same age as that of the Sierra Nevada, while Lawson suggests in his paper on

*Journal of Geology, vol. II, pp. 32-54.

'The Geomorphogeny of the coast of northern California"* that this peneplain of the Sacramento valley may be the same as the one he describes in that paper, and this Coast Range peneplain he shows to be Pliocene or later in age. While this article is merely suggestive of future work, it would be very incomplete without reference to Kemp's "Ore Deposits of the United States," of which a new and revised edition has just been issued (1895). Prof. Kemp discusses the age of the Auriferous gravels, and gives very full references to the literature.

At the present time it appears injudicious to the writer to consider the age of even the older gravels as a settled question. Much light may be expected when the collections of fossil plants from these gravels now in the U. S. National Museum are thoroughly investigated, and compared with floras from other localities in western America.

EDITORIAL COMMENT.

The Deep Shaft at Livonia, N. Y.

A very interesting contribution to economic geology and especially to the knowledge of the succession of faunas in some of the Paleozoic rocks is the account of geological results from the excavation of the Livonia salt shaft in Livingston county, N. Y., as given by Mr. D. D. Luther, in the Thirteenth Annual Report of the state geologist of New York (1895). Probably never before has a geologist had the opportunity of observing on such a grand scale the consecutive variations in sedimentation and in associations of organic forms as has been afforded by this immense probe into the Devonian rocks. Here is a shaft measuring 14 by 24 feet and extending to a depth of 1,432 feet, which means that nearly 20,000 cubic yards of sedimentary and fossiliferous rock were taken out, foot by foot, in vertical sequence, and all of this was spread out, in order, under the eyes of a geologist.

*Bull. Dept. Geol. Univ. Cala., vol. I, p. 271.

Such enterprises as sinking deep wells and shafts are, as every geologist has learned, usually executed without much demonstration, perhaps because of the possibility of disappointment which they carry with them. The geologist often hears of them only by accident, and then too late to secure accurate information, so that the average well or shaft record is of very little value in determining thicknesses of successive strata. But it appears from Prof. Hall's introductory chapter to this report that a personal invitation was extended to him by the officers of this salt company, to keep a geologist on the ground during the progress of these excavations, which otherwise would not have become widely known except to those financially interested in them. Nearly two years were occupied in sinking this shaft, although there was apparently some delay in getting the geological watcher on the ground, as Mr. Luther's actually recorded entries began 320 feet below the surface. It is stated, however, that the succession above this was accurately made out from natural sections in the vicinity, aided by the debris taken from the shaft. The report is lucid,concise, free of padding, and well illustrated.

The section is, of course, important in its bearing upon the geology of the salt in western New York, and must be of no little value to those practically interested in the result of this extensive industry in that region; but its highest service is the determination of an unimpeachable record of stratigraphic and organic succession. The rock series traversed is from the lower part of the upper Devonian (lower Portage) to the salt beds, near the middle of the Salina group, and some of its more striking peculiarities may be briefly stated. The last 327 feet of the section are unfossiliferous hydraulic limestones, gypsums and marls. Just above them, or rather, in their upper part, is a well developed Tentaculite limestone fauna, extending through a vertical thickness of 35 feet, which alone represents the entire Lower Helderberg formation so distinctly differentiated in its typical and more eastern exposures. Overlying this is a conglomerate of blocks of hydraulic limestone cemented by a silicious sand. The hydraulic blocks appear to have been derived from the underlying strata, and are without fossils, while the cement contains species occurring elsewhere in the Oriskany sandstone and the Schoharie

grit, or the later Upper Helderberg faunas. Near the top of the Corniferous limestone is a remarkable layer composed of minute gypsum crystals in an amorphous gypsum base. After the appearance of the fauna of the Marcellus shales, there was an abrupt return, for a brief period, of many of the Corniferous species, and when these had disappeared and a characteristic Marcellus fauna had again held sway for a considerable time, there was an abrupt appearance of a highly developed Hamilton shales fauna (Stafford limestone) which, again, soon retreated, leaving the field to the Marcellus species and their bituminous environment. The influences of the Marcellus conditions, both physical and organic, are carried far upward beyond their usual limit, and the return of the Hamilton fauna, together with the elimination of the bituminous matter from the sediments, is a very gradual process. Throughout the entire section the range and individual development of each species are carefully recorded. Mr. Luther's report is supplemented by some paleontological notes and descriptions by J. M. Clarke.

The real geological importance of such deep shafts can not be overestimated as the results derived therefrom have a mathematical precision. We learn that the preparations for the monster exposition at Paris in 1900 are contemplating a proposition from deputy M. Paschal Grousset to put down a shaft on the exposition grounds 1,500 meters, or about a mile, in depth. If such an exploit were feasible (the increase of temperature downward would probably curtail it), it would certainly be a most profitable venture on behalf of exact stratigraphy and terrestrial physics, although it might not settle the questions which M. Grousset wishes to elucidate and which are thus stated by a special correspondent: "(1) Whether the theory of the central fire of the earth be fact or fiction, (2) whether this source of internal heat, if such exist, be accessible or utilizable, (3) whether or not the sub-soil of Paris serves as a roof to a vast ocean of soft water." The language is as bold as the proposition, and if such amazing conditions exist beneath Paris, it is certainly high time the Parisians did something about it.

THE EARTH'S AGE.

In the first number of *Nature* for the present year (vol. 51, pp. 224-227, Jan. 3, 1895), Prof. John Perry of London published a criticism of the estimate reached long ago by Sir William Thomson (now Lord Kelvin), from consideration of the earth's present crustal temperature, the downward increase of its heat, and its probable original temperature when first beginning to cool and become encrusted, that the duration of geologic time represented by the sedimentary formations is between 20 and 400 million years, and that probably this duration must be no more than 100,000,000 years. Professor Perry, however, assuming an increased rate of conductivity of rock at very high temperatures, worked out the problem anew, obtaining the result that the earth's cooling to its present temperature gradient has required more than 9,600,000,000 years. This conclusion had been submitted in correspondence to Lord Kelvin, whose reply, following Prof. Perry's discussion, acknowledges the need of further experiments on the thermal conductivity of rocks, but doubts that it would be found to vary so as to justify Perry's greatly increased estimate of geologic time.

During the same month (last January) Lord Kelvin conducted some experiments on highly heated rocks, confirming earlier work by Dr. Robert Weber, which together show that conductivity does not increase with temperature, which increase Prof. Perry had assumed. Instead, it is found that basalt and marble are practically unchanged in conductivity, while rock salt, anhydrite, and quartz show an important decrease. Lord Kelvin therefore, in a recent short article in *Nature* (vol. 51, pp. 438-440, March 7, 1895), still holds to his original figures, or is even inclined to reduce them. He quotes somewhat fully, and with approval, the paper on this subject by Mr. Clarence King in the *American Journal of Science* for January, 1893, based on the laboratory experiments of Dr. Carl Barus, with diabase under great heat and pressure, for the U. S. Geological Survey. This investigation, indicating that the earth's age scarcely exceeds the minimum limit of Lord Kelvin's earlier estimates, is now regarded by him as probably very near to the truth. Kelvin says of King's investigation: "I am not led to differ much from his estimate of

24 million years. But, until we know something more than we know at present as to the probable diminution, or still conceivably possible augmentation, of thermal conductivity with increasing temperature, it would be quite uninteresting to publish any closer estimate."

Lord Kelvin further directs attention to the physical and astronomic investigations of Helmholtz, Newcomb, and others, who have shown that the sun's light and heat can have been supplied as now probably no longer than a score or a very few scores of million years. His article ends with the following quotation from the conclusion of King's paper: "The concordance of results between the ages of sun and earth certainly strengthens the physical case, and throws the burden of proof upon those who hold the vaguely vast age, derived from sedimentary geology."

It thus appears, according to the physicists, that the facts of geology and of biologic evolution have occupied less time than we might suppose indispensible from observations on the rate of changes during the recent and historic period. Geologists and paleontologists, however, will be reluctant to accept so meager an allowance of time, and it seems very desirable that observations from all sources bearing on the problem shall be placed on record. Such observations are obtained by Mr. G. K. Gilbert from field work for the U. S. Geological Survey in Colorado, where, as stated by him in the last number of the *Journal of Geology* (vol. III, pp. 121-127), he suggests, from alternations of shale and limestone deposits, thought to be perhaps referable to the astronomic cycles of precession of the equinoxes and nutation, that only a part of the Cretaceous series may represent a duration of some 20,000,000 years. This implies one of the highest estimates for the age of the earth which has ever been founded on the rate of sedimentation. It is quite incompatible with the physical and astronomic estimates before noted, and indeed it far transcends the commonly supposed needs of geology and biology. These might well be content with Kelvin's 100 million years, but cannot well see room for their history if that time must be reduced to King's 24 million years. W. U.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

The Geology of Minnesota. Volume III. Part I. of the Final Report. Paleontology. N. H. WINCHELL, State Geologist. (Roy. 4to, pp. i-lxxv, 1-474, 41 plates, 1895.) Professor Winchell announced, in one of his recent annual reports, that this volume of his final reports would embrace only a part of the paleontological chapters, and that the others would have to appear through some different channel. Evidently, however, there has been a happy change of plan, by which this part of volume III, with one to follow, will comprehend accounts of all of the more important groups of fossils from the geological formations of the state, especially those of the Silurian. Part I, like the other members of the series of final reports, is an elegant and tasteful book, sumptuous in its large quarto form and beveled boards, creditable in its press-work and superior in its lithography, especially in that of the 28 plates accompanying Mr. Ulrich's memoir on Lower Silurian Bryozoa. The zinc-plates illustrating Messrs. Winchell and Schuchert's chapters on sponges, graptolites and corals, and on the Brachiopoda are effective and serviceable.

The book is introduced by an "Historical Sketch of Investigations of the Lower Silurian in the upper Mississippi Valley," by PROF. WINCHELL and Mr. E. O. ULRICH. This is a valuable summary of all studies, incidental and protracted, of these formations in the state or its immediate vicinity. "The paleontology of the Lower Silurian," say the authors, "as exemplified in the rocks of Minnesota and adjoining states, has been strangely overlooked and neglected." Were the case different the state geologist might not have felt called upon to produce the important treatises in this book, and science will not, in the light of the present, complain of these omissions of the past.

Chapter I is a description of the "Cretaceous Fossil Plants from Minnesota," by the late LEO LESQUEREUX, and is accompanied by two plates of leaves. A considerable portion of it is devoted to some general considerations pertaining to the distribution and derivation of the American Cretaceous flora, and is followed by descriptions of 28 species from Minnesota, 6 of which are new, 14 occurring in the beds of Kansas and Nebraska, and 6 in those of Greenland.

Chapter II is entitled "The Microscopal Fauna of the Cretaceous in Minnesota, with additions from Nebraska and Illinois (Foraminifera, Radiolaria, Coccoliths, Rhabdoliths,)" by ANTHONY WOODWARD and BENJAMIN W. THOMAS. It is prefaced by some rather inconsequent observations on the importance of the microscope in paleontology and the significance of certain Devonian accumulations of spores to the oil-product of Ohio, followed by an account of the authors' preparative methods. The descriptions of the species are, for the most part extremely brief, rarely more than a reproduction of the original descriptions, but identifications bear evidence of having been made with extreme

care and with a remarkable command of literature. There are three plates of good figures accompanying the paper, but it is unfortunate that the degree of enlargement represented by these figures is not given in each case, as in but a few instances is the actual size of species stated in the descriptions. A most unusual and striking feature of this chapter, however, speaking worlds for the authors' diligent and patient study of the work of other writers, is that not a single new species is described. Prof. Winchell follows this paper with brief remarks on the occurrence of other Cretaceous fossils in Minnesota.

Chapter III, "Sponges, Graptolites and Corals from the Lower Silurian of Minnesota," by N. H. WINCHELL and CHARLES SCHUCHERT, was briefly noticed in the AMERICAN GEOLOGIST (vol. XII, p. 331) at the time of its first appearance in the separate form. It is accompanied by two zinc plates. The chapter opens with a compiled description of the genera *Receptaculites* and *Ischadites*, followed by synopses of the American species; and briefly discusses the imperfectly known *Lepidolites*, Ulrich, which shows some close affinities to the latter genus. At this point is introduced an important contribution by Mr. ULRICH bearing upon the nature of the genus *Anomalospongia*. As the external form of this sponge has not been made out, the author's observations and inferences are based wholly on a portion of the spicular structure. This is certainly most interesting. The dermal wall is composed of very closely set spicules having three horizontal arms, each of which is biaxial. The entering ray is enormously swollen and the continuation of its axis beyond the horizontal rays is atrophied to a node. The aspect of the spicule is that of a pentactin. With another horizontal ray it might well be compared to a similar appearing structure in *Receptaculites*. Did the outer node, representing the continuation of the vertical axis, not exist, the form might be understood as a modification of a tetractin, but, as it is impossible to set aside the node as a fortuitous or incidental occurrence, the spicule certainly seems to be an "anomalous" pentactin whose derivation it is difficult to understand. The author states that "the sponge was probably originally silicious," but it would hardly be possible that such a spicular form could be a derivative of the hexactin. If its relations are with *Receptaculites*, a genus which, on some hands, is regarded as neither silicious nor a sponge, it may have to follow that in its taxonomic wanderings; one could, however, scarcely question the sponge nature of *Anomalospongia*, and it is to be hoped that more may be learned of its external form. To the family *Dictyospongidæ* is referred the genus *Rauffella*, Ulrich. We believe Mr. Ulrich's previous arrangement has here been followed, but in this instance it is palpably incorrect. The fossil shows no relation to the dictyosponges, and Rauff, who seems to have had specimens in hand, protests, with suicidal intent, that it is not an organism. The German spongist also suggests that some of Ulrich's genera, which are referred to the pharetrones, are lithistids, and he has further regarded the species *Hindia parva* Ulrich as a synonym for, or, at most, a variety of *H. sphæroidalis* Duncan, but the latter view may be ascribed to personal dissimilarities in the apprehen-

sion of specific values. The portion of this chapter which treats of the sponges is the most lengthy and important. One may wonder how any writer could adopt such an incongruous lot of family names as *Receptaculitidæ*, *Dictyospongidæ*, *Pharetrones* and *Tetracladina* without disguising the value of the observations here brought together and which are, for the most part, those of Mr. E. O. Ulrich. Besides the forms referred to, a few species of graptolites and corals are described, among them the type of a new genus of Zoantharia, *Lichenaria typa*. In all, the chapter embraces illustrated descriptions and reviews of 21 species: but five of these are new, and three of this five are accredited to Mr. Ulrich.

Chapter IV is "On the Lower Silurian Bryozoa of Minnesota," by E. O. ULRICH, extends from p. 96 to p. 332, and is illustrated with 28 plates. This important chapter has already been briefly referred to in the AMERICAN GEOLOGIST (vol. XII, p. 331) and no appreciative review of its contents can now be given. This group of small and complex fossils has so long enlisted the author's best activity, that few students have followed him closely enough to be entitled to express anything but encomiums upon his accomplishments. The paper opens with introductory pages upon the morphology, terminology, preservation and methods of study, classification and geological distribution. "To the Bryozoa," the author writes, in his opening paragraph, "must be accorded the first rank among the various classes that are represented in the Lower Silurian rocks of Minnesota. They are entitled to this distinction, first, because of the great variety of form and structure found among them, and, second, because of their exceeding abundance." Elsewhere, as here, Mr. Ulrich has claimed the Bryozoa as the best horizon markers of the earlier Silurian, and he may be fully justified in the claim, even though a faunal division on such a basis is beyond the grasp of the majority of paleontologists. The descriptions are perspicacious, the observations acute and penetrating and the results are of fundamental value.

Chapter V, "The Lower Silurian Brachiopoda of Minnesota," by N. H. WINCHELL and CHARLES SCHUCHERT, covers pp. 333-474 and plates 29-34. Twenty-nine new species and varieties are described, most of these descriptions having already been published in the AMERICAN GEOLOGIST.

J. M. C.

The Geology of Conanicut Island, R. I. By G. L. COLLIE. (Trans. Wisconsin Acad. Sci., Arts and Letters, vol. X, pp. 199-230, pl. 4, March, 1895.) This is a small island lying in Narragansett bay, just west of Newport. The main part of the island consists of a series of schists, often graphitic, with some interbedded grits and conglomerates, the whole presenting a thickness of 1,200 feet. In the lower portion of this series Carboniferous plants have been found. Unconformably below the schist series is a coarse porphyritic biotite granite and a green flinty slate of unknown age. The granite is of more recent date than the slate. The author presents evidence to show that the above is the true structure, in opposition to the idea that the schists and the slate are of the same age and that the latter is only an altered phase of the former,

its differences being due to contact with the granite. All the rocks of the island have been subjected to intense dynamic action and a number of minerals have been developed in the schists, among which are garnet, andalusite and ottrelite. Cutting the rocks of the island are a series of dikes whose structure and composition ally them with the minettes. U. S. G.

The Geomorphogeny of the Coast of northern California. By ANDREW C. LAWSON. Bulletin of the Department of Geology, University of California, vol. I, No. 8, pp. 241-271. (Berkeley, Nov., 1894.) This paper supplements Prof. Lawson's former study of the diastrophism of the California coast south of San Francisco (reviewed in the AM. GEOLOGIST, vol. XIV, pp. 335-338, Nov., 1894). The sequence of the Pliocene and Pleistocene history of the coast farther north is given as follows: 1. The development in Pliocene time of a great coastal peneplain, with correlative accumulation of marine sediments. A delta formation in Humboldt county, called the Wild-cat series, measures about one mile in thickness perpendicular to the dip of the strata, which ranges from 15° to 25°. 2. The orogenic deformation of parts of the peneplain and the folding of the Pliocene strata, the general altitude of the peneplain, where not so disturbed, remaining about the same. 3. The reduction of the upturned soft Pliocene strata to base-level, and the limited extension of the peneplain in between the uplifted blocks of the other disturbed areas. 4. Pleistocene epeirogenic uplifting of the peneplain, with its residual monadnocks, to an elevation for the plain of from 1,600 to 2,100 feet above the sea level, the adjacent mountainous tracts participating in the same movement. 5. The advance in the new geomorphic cycle to a stage of late adolescence or early maturity. 6. A very recent local sag or depression of about 100 miles of the coast adjacent to the Golden Gate, and the consequent flooding of the stream valleys by the ocean. The subsidence known by the depth of water in the narrowest part of the Golden Gate is at least 378 feet.

In the vicinity of cape Mendocino, which is in Humboldt county, the early Pleistocene epeirogenic movement appears to have elevated the land for a geologically very short time to an altitude about 3,000 feet above its present hight, as shown by the submarine fjords which Prof. George Davidson has found by soundings for the U. S. Coast Survey. This maximum extent of the uplift is not considered in the present paper, but it seems to have been very important in its results as the chief cause of the accumulation of the Pleistocene ice-sheet, having been a part of the great epeirogenic uplift which affected the whole width of the continent to the mouth of the Hudson river, with its similarly deep submerged fjord. W. U.

Annals of British Geology, 1893. *A digest of the books and papers published during the year, with an introductory review.* By J. F. BLAKE. (London, Dulau & Co., 1895.) This annual contribution to the geology of the world consists, as its title explains, of a synoptical digest of the progress made by British geologists. It would be well if every coun-

try's contribution could be summarized in like manner. It is of great value to workers outside of Britain, where the special literature of Britain is less accessible. The editor's introductory review is the most valuable single part of the volume, especially to geologists not resident in Britain. It may be objected that necessarily such a review is tainted by the coloring which it may receive from the reviewer's own ideas. But that we do not deem a fault. Every competent geologist is entitled to his opinion and to the right to make it effective, and any geologist who by great labor contributes to the general fund and to the clearness of the geological ideas current in his day, is a benefactor to the science. He should not be required to renounce his individuality nor to smother his sentiments. Besides, if any geologist puts himself under the burden of annually condensing and publishing the work of British geologists, he should be accorded the presumptive possession of geological acumen sufficient to guide him, and a sufficiently high sense of fairness to make him render justice in his judgments. He must be a geologist who is personally devoted to the cause of geology and to hard work. If he have his own ideas on some geological questions they will be pretty likely to be grounded on the best of evidence.

This is the fourth volume of this series, which began with the year 1890. The four volumes are sold at thirty shillings. N. H. W.

Results of a Transcontinental Series of Gravity Measurements. By GEORGE ROCKWELL PUTNAM. *Notes on the Gravity Determinations Reported by Mr. G. R. Putnam.* By GROVE KARL GILBERT. (Philosophical Soc. of Washington, Bull. vol. 13, pp. 31-76, pl. 5, April, 1895.) Some important geodetical work has been recently undertaken by Mr. G. R. Putnam in connection with the United States Geological Survey in the carrying out of a series of pendulum experiments to determine the force of gravity at various points in North America. This subject has received much attention from physical geologists, especially since the publication of the results of Maskelyne's experiments on Schehallion, and later of those of Pratt in the Himalayas and of Airy in a coal mine in the north of England. Pratt's results seem to indicate that the material of the Himalayas was of less specific gravity than the adjoining crust, so that the deviation of the plumb line from the true vertical was less than it should have been had the density of both been equal.

The difficulty and cost of the necessary experiments have in the past been a great barrier in the way of physicists who desired to repeat and extend them. But by the employment of a half-second or quarter-metre pendulum these obstacles were so far reduced as to render the task one of comparative ease, and twenty-six stations were occupied and observations made at each of them during five months of 1894.

A statement of his results is given by Mr. Putnam in a tract published by the Philosophical Society of Washington, and following it is a short discussion of the results by Mr. G. K. Gilbert.

Elaborate corrections are applied to the figures obtained by observation whereby they are reduced to those for latitude 40° and to sea-level,

the object being to ascertain whether or not they yield support to the theory of isostasy. This theory of course requires less gravitational effect on sea-level in an elevated region than in one lying lower, in consequence of the loss of the positive and the presence of the negative attractive action of the elevated mass, the earth's whole surface being assumed by the theory to be in gravitational equilibrium, an assumption which may, however, be equally true on the theory of rigidity.

At eleven stations from Ithaca, N. Y., to Denver, Colo., the gravitational co-efficient was found to average 980.151 dynes, the small variations from this mean (which was obtained at Ithaca) showing no relation to the altitude of the station. On reaching the mountains, however, the reduced figures show at once a high excess above the average for the plain, being at Pike's peak 980.229 dynes. The isostatic theory requires that they be less. The same is true in a less degree at all the mountain stations to Salt Lake City exclusive, except at Grand Junction and Green River. Obviously these results give no support to the doctrine of isostasy, and Mr. Gilbert says, "Gravity exceeds the isostatic requirement by 2,300 or 2,200 rock-feet. The evident suggestion is that the whole Rocky Mountain plateau, regarded as a prominence on a broader plateau, is sustained by the rigidity of the lithosphere." "The group of stations in the Yellowstone park repeats the suggestion for the Rocky mountains of Montana." The two stations on the Colorado plateau give very discordant results. At Grand Junction, gravity was found to equal 980.198 dynes, an excess of 0.047 dyne, while at Green River it was 980.136 dynes, a defect of 0.015 dyne, a difference of 1,800 rock-feet, which is not at present explicable. The same difficulty was encountered at Washington and Philadelphia.

On the whole, Mr. Gilbert says that he inclines to the conclusion that the mountains are upheld by the rigidity of the lithosphere, but that the great interior plain is in a state of approximate isostatic equilibrium.

We may hope that the interest and value of such observations will lead to their continuance. The argument must be cumulative when the total amounts are so small and the variations so discordant. At present we do not feel that the results tell with any force in favor of either theory to the exclusion of the other. The unknown factors in the problem are important and the danger of error is great. E. W. C.

RECENT PUBLICATIONS.

I. Government and State Reports.

Geol. Sur. of Georgia, Bull. No. 1. A preliminary report on the marbles of Georgia, S. W. McCallie. 92 pp., 16 pls., 2 maps, 1894.

Geol. Sur. of Georgia. Administrative report of the State Geologist for the year ending Oct. 23, 1894, W. S. Yeates. 9 pp., 1894.

Geol. Sur. of New Jersey, Ann. Rept. of the State Geol. for the year 1893, ix and 457 pp., 10 pls., 1894; accompanied by 4 maps. Contains: Administrative report, J. C. Smock; Surface geology, report of progress, R. D. Salisbury; Drift phenomena of the Palisade ridge, R. D. Salisbury and C. E. Peet; Lake Passaic, an extinct glacial lake, R. D. Salisbury and H. B. Kümmel; Cretaceous and Tertiary geology, report of progress, W. B. Clark; The geological structure in the vicinity of Hibernia, New Jersey, and its relation to the ore deposits, J. E. Wolff; Water supply and water power, C. C. Vermeule; Artesian wells and water horizons in southern New Jersey, with economical, geological and paleontological notes, Lewis Woolman; Minerals of New Jersey and notes of mineral localities.

Iowa Geol. Sur., vol. 3, 2d Ann. Rept., 1893, 501 pp., 37 pls. Contains: Report of State Geologist, Samuel Calvin; Report of Assistant State Geologist, C. R. Keyes; Report of Chemist, G. E. Patrick; Work and scope of the Geological Survey, C. R. Keyes; Cretaceous deposits of the Sioux valley, H. F. Bain; Certain Devonian and Carboniferous outliers in eastern Iowa, W. H. Norton; Geological section along Middle river in central Iowa, J. L. Tilton; Glacial scorings in Iowa, C. R. Keyes; Thickness of the Paleozoic strata of northeastern Iowa, W. H. Norton; Composition and origin of Iowa chalk, Samuel Calvin; Buried river channels in southeastern Iowa, C. H. Gordon; Gypsum deposits of Iowa, C. R. Keyes; Geology of Lee county, C. R. Keyes; Geology of Des Moines county, C. R. Keyes.

Rept. of the Dept. of Mines, Nova Scotia, for the year ending Sept. 30, 1894. By Edwin Gilpin, Jr. 8vo, 80 pp., 1894.

Summary report of the Geological Survey Department (Canada) for the year 1894, G. M. Dawson, Director. 126 pp., 1895.

Illinois State Museum, Bull. No. 6. Description of new species of Palæozoic Echinodermata, S. A. Miller and W. F. E. Gurley. 62 pp., 5 pls., Apr. 5, 1895.

Geol. and Nat. Hist. Survey of Minn., Final Report, vol. 3, pt. 1, lxxv and 474 pp., 41 pls., 1895. Contains: Historical sketch of investigation of the Lower Silurian in the upper Mississippi valley N. H. Winchell and E. O. Ulrich; Cretaceous fossil plants from Minnesota, Leo Lesquereux; The microscopical fauna of the Cretaceous in Minnesota, with additions from Nebraska and Illinois, Anthony Woodward and B. W. Thomas; Note on other Cretaceous fossils in Minnesota, N. H. Winchell. Sponges, graptolites and corals from the Lower Silurian in Minnesota, N. H. Winchell and Charles Schuchert; On Lower Silurian Bryozoa of Minnesota, E. O. Ulrich; The Lower Silurian Brachiopoda of Minnesota, N. H. Winchell and Charles Schuchert.

II. Proceedings of Scientific Societies.

Bull. of the Amer. Museum of Nat. Hist., vol. 6, 1894, contains: Osteology of Patriofelis, a middle Eocene creodont, J. L. Wortman; Fossil mammals of the lower Miocene White River beds, collection of 1892, H. F. Osborn and J. L. Wortman; On new forms of marine Algæ from the

Trenton limestone, with observations on Buthograptus laxus, Hall, R. P. Whitfield.

Bull. Geol. Soc. Amer., vol. 6, pp. 199-220. Feb., 1895. Recent glacial studies in Greenland, T. C. Chamberlin.

The same, pp. 221-240, March, 1895. Characteristic features of California gold-quartz veins, Waldemar Lindgren.

The same, pp. 241-262, March, 1895. Crystalline limestones, ophicalcites and associated schists of the eastern Adirondacks, J. F. Kemp.

The same, pp. 263-284, March, 1895. Crystalline limestones and associated rocks of the northwestern Adirondack region, C. H. Smyth, Jr.

The same, pp. 285-296, March, 1895. Faults of Chazy township, Clinton county, New York, H. P. Cushing.

The same, pp. 297-304, March, 1895. Honeycombed limestones in lake Huron, Robert Bell.

The same, pp. 305-320, March, 1895. The Pottsville series along New river, West Virginia, David White.

The same, pp. 321-332, March, 1895. Disintegration of the granitic rocks of the District of Columbia, G. P. Merrill.

The same, pp. 333-342, March, 1895. Tepee buttes, G. K. Gilbert and F. P. Gulliver.

The same, pp. 343-352, Apr., 1895. Discrimination of glacial accumulation and invasion, Warren Upham.

The same, pp. 353-374, Apr., 1895. Glacial lakes of western New York, H. L. Fairchild.

The same, pp. 375-388, April, 1895. Cretaceous of Western Texas and Coahuila, Mexico, E. T. Dumble.

The same, pp. 389-422, Apr., 1895. Highwood mountains of Montana, W. H. Weed and L. V. Pirrson.

The Geol. Soc. of Washington. Presidential address, The United States Geological Survey, by C. W. Walcott. With abstracts of minutes and lists of officers and members, 1893-1894. 46 pp., Washington, Mch., 1895.

Bull. Amer. Geog. Soc., vol. 27, No. 1, 1895, contains: The mapping of New York state, Henry Gannett; Reports of a conference on geography, I. C. Russell; The United States Geological Survey in 1894, Marcus Baker.

III. Papers in Scientific Journals.

American Journal of Science, April, 1895, contains: Niagara and the Great lakes, F. B. Taylor; Disturbances in the direction of the plumb-line in the Hawaiian islands, E. D. Preston; Glacial lake St. Lawrence of Prof. Warren Upham, R. Chalmers; Epochs and stages of the Glacial period, Warren Upham; Structure and appendages of Trinucleus, C. E. Beecher.

American Journal of Science, May, 1895, contains: Sketch of J. D. Dana, with portrait; Further notes on the gold ores of California, H. W. Turner; Improved rock cutter and trimmer, Edgar Kidwell.

School of Mines Quarterly, Jan., 1895, contains: Garnet as an abrasive

material, F. C. Hooper; Analysis of Cretaceous clays from Long Island, C. H. Joüet.

American Naturalist, April, 1895, contains: On the presence of flourine as a test for the fossilization of animal bones, Thomas Wilson; Observations on a so-called petrified man, J. M. Stedman; On the validity of the genus Margaritana, C. T. Simpson.

Science, March 22, 1895, contains: Current notes on physiography (IV), W. M. Davis.

Science, April 19, 1895, contains: On the marine mollusks of the Pampean formation, H. von Ihering.

Science, April 26, 1895, contains: The Protolenus fauna, G. F. Matthew; Volcanic dust in Texas, H. W. Turner.

Science, May 3, 1895, contains: Current notes on physiography (V), W. M. Davis; Letter to J. D. Dana.

Science, May 10, 1895, contains: Current notes on physiography (VI), W. M. Davis.

Journal of Geology, Feb.-March, 1895, contains: Sedimentary measurement of Cretaceous time, G. K. Gilbert; Use of the aneroid barometer in geological surveying, C. W. Rolfe; A petrographical sketch of Ægina and Methana, pt. 3, H. S. Washington; On Clinton conglomerates and wave marks in Ohio and Kentucky, A. F. Foerste; Glacial studies in Greenland, IV, T. C. Chamberlin.

Journal of Geology, April-May, 1895, contains: The classification of European glacial deposits, James Geikie; The classification of American glacial deposits, T. C. Chamberlin; The variations of glaciers, H. F. Reid; Stratigraphy of the Saint Louis and Warsaw formations in southeastern Iowa, C. H. Gordon; Algonkian rocks of the Grand canyon of the Colorado, C. D. Walcott; New light on isostasy, G. K. Gilbert; James D. Dana as a teacher of geology, O. C. Farrington.

Ottawa Naturalist, Apr., 1895, contains: The Rensselaer grit plateau, R. W. Ells.

Ottawa Naturalist, May, 1895, contains: On some dykes containing huronite, A. F. Barlow.

American Naturalist, May, 1895, contains: On the presence of fluorine as a test for the fossilization of animal bones, Thomas Wilson.

IV. Excerpts and Individual Publications.

The Costilla meteorite, R. C. Hills. Proc. Colo. Sci. Soc.; 2 pp. and plate; read Jan. 7, 1895.

The Potsdam and Calciferous formations of Quebec and eastern Ontario, R. W. Ells. Trans. Roy. Soc. Canada, sec. 4, 1894, pp. 21-30.

A synoptical index of the fossils of Missouri, C. R. Keyes. Mo. Geol. Sur., vol. v, pp. 241-266, 1894.

A stratigraphic catalogue of Missouri fossils, C. R. Keyes. Mo. Geo. Sur., vol. IV, pp. 241-264, 1894.

The apatite-bearing rocks of the Ottawa district, R. W. Ells. Canadian Rec. Sci., pp. 213-222, Jan., 1895.

A history and descripton of magnesia and its base and compounds,

with particular reference to magnesite, H. G. Hanks. 27 pp., San Francisco, 1895.

Catalogue of recognized Palæozoic sponges of North America. W. R. Head. 11 pp. March 1, 1895.

Notes on the Texas Tertiaries, E. T. Dumble. Trans. Texas Acad. Sci., pp. 23-27, read June 19, 1894.

L'eboulis de St. Alban, Mgr. Laflamme. Trans. Roy. Soc. Canada, sec. 4, 1894, pp. 63-70.

Elements of mineralogy, crystallography and blow-pipe analysis from a practical standpoint. A. J. Moses and C. L. Parsons. 8vo., 342 pp., New York, D. VanNostrand Co., 1895.

Oil and gas in Kansas, Erasmus Haworth. Proc. A. A. A. S., vol. XLIII, 1894, 8 pp,

The geology of Conanicut island, R. I., G. L. Collie. Trans. Wis. Acad. Sci., Arts and Let., vol. x, pp. 199-230, pl. 4, March, 1895.

Results of a transcontinental series of gravity measurements, G. R. Putnam. Philosophical Soc. of Washington, Bull. vol. XIII, pp. 31-60, April, 1895.

Notes on the gravity determinations reported by Mr. G. R. Putnam, G. K. Gilbert. Same, pp. 61-76.

The mineral development of Nova Scotia, Edward Gilpin. Trans. Federated Inst. Mining Eng., 1894, 15 pp.

New and otherwise interesting Tertiary Mollusca from Texas, G. D. Harris. Proc. Acad. Nat. Sci. Phila., pp. 45-88, pls. 1-9, 1895.

The discovery and development of the iron ores of Minnesota, N. H. Winchell. Minn. Hist. Soc. Collections, vol. VIII, pt. 1, pp. 25-40, map, 1895.

Interloessial till near Sioux City, Iowa, J. E. Todd and H. F. Bain. Proc. Iowa Acad. Sci., 1894, vol. II, pp. 20-23, pl. 1, 1895.

Preglacial elevation of Iowa, H. F. Bain. Same, pp. 23-26.

V. *Proceedings of Scientific Laboratories, etc.*

Bull. Dept. of Geol., Univ. of California, vol. 1, no. 8, pp. 241-272, Nov. 1894, contains: The geomorphogeny of the coast of northern California, A. C. Lawson.

Bull. of the Illinois State Mus. Nat. Hist., Champaign, Ill., pp. 36-137, 1894, contains: List of altitudes in the state of Illinois, C. W. Rolfe.

Univ. of Cal., Bull. Dept. of Geol. On analcite diabase from San Luis Obispo Co, California, H. W. Fairbanks. Vol. I, no. 9, pp. 273-300, pls. 15-16, Jan., 1895.

Bull. Mus. Comp. Zool, vol. XXVI, no. 1. A reconnoissance of the Bahamas and of the elevated reefs of Cuba in the steam yacht "Wild Duck," January to April, 1893, Alexander Agassiz. 203 pp., 47 pls., Dec., 1894.

Kansas Univ. Quart., Jan., 1895, contains: New or little known extinct vertebrates, S. W. Williston.

Bull. Mus. Comp. Zoöl., vol. XXVI, no. 2: A visit to the Bermudas in March, 1894. Alex. Agassiz. Pp. 205-281, pls. 1-30, April, 1895.

The same, vol. XVI (Geol. Ser., vol. II), no. 15; Notes on the geology of the island of Cuba, R. T. Hill. Pp. 243-288, pls. 1-9, April, 1895.

Bull. Univ. of Wisconsin, science series, vol. 1, no. 2: On the quartz keratophyre and associated rocks of the north range of the Baraboo bluffs, Samuel Weidman. Pp. 35-56, pls. 1-3, Jan., 1895.

Colorado College Studies, 1894, contains: The origin and use of the natural gas at Manitou, Colorado, Wm. Strieby; The Choctaw and Grayson terranes of the Arietina, F. W. Cragin; Descriptions of new species of Invertebrata from the Comanche series in Texas, Indian Territory and Kansas, with definition of two Comanche terranes, F. W. Cragin; Vertebrata from the Neocomian of Kansas, F. W. Cragin.

Kansas Univ. Quarterly, vol. III, no. 4, April, 1895, contains: Semi-arid Kansas, S. W. Williston; The stratigraphy of the Kansas Coal Measures, Erasmus Haworth; Division of the Kansas Coal Measures Erasmus Haworth; the coal fields of Kansas, Erasmus Haworth.

CORRESPONDENCE.

A CORRECTION. In the writer's recent papers entitled "The Second Lake Algonquin" (AMERICAN GEOLOGIST, Feb. and March, 1895), and "Niagara and the Great Lakes" (Am. Jour. Sci., April, 1895), the name "Erigan" was adopted from Prof. J. W. Spencer's writings and used as the name of a section of the Niagara gorge and of the river which made that section. This course was adopted with the best of intentions. It was supposed that it would be the closest possible conformity to previous use. But it is learned by a recent letter from Prof. Spencer that the writer's use of the name Erigan is entirely different from his. The mistake would probably not have occurred, but for an unfortunate combination of circumstances, including the loss of a reprint in which Prof. Spencer originally used the name, and also the absence of Prof. Spencer in Jamaica and southern Mexico and the consequent failure of the writer to get an answer to a letter of inquiry addressed to him early in the winter. For these reasons the writer was led to rely solely upon his memory. Prof. Spencer's Erigan river, like that so named by the writer, drained only lake Erie. But it was entirely pre-Glacial and it followed the Grand River valley northward to the Dundas valley at the west end of lake Ontario and hence did not occupy the Niagara channel at all. (See "Origin of the Basins of the Great Lakes of America" by J. W. Spencer. Quart. Jour. Geol. Soc., Nov., 1890, map page 2.) In the writer's articles referred to above the use of the name Erigan is confined in the first to pages 167 to 179, and in the second to pages 266 to 270. In place of that name it is proposed to substitute the name "Little Niagara." This will be the name of the river which made the narrow, shallow gorge of the Whirlpool rapids, and that part of the gorge may be called the Little Niagara gorge. It is believed that the

substitution of this name throughout for "Erigan" will remove the difficulty and obviate so far as is now possible the confusion which might otherwise arise. F. B. TAYLOR.

Fort Wayne, Ind., May 10. 1895.

A QUESTION OF PRIORITY. In the summer of 1892, while making a geological examination in northwestern Texas, I found and collected a lot of vertebrate fossils from strata above the Loup Fork beds and below the beds I had previously described under the name of Blanco beds.* These fossils, with others, were sent to Prof. E. D. Cope for identification and description. His paper was published in May. 1893.† In that paper he said:

"A small collection made by Mr. Cummins, near Goodnight, on the Staked plains, presents characters which distinguish it from the faunæ of the Loup Fork and Blanco formations. According to Mr. Cummins, the Loup Fork formation is overlaid by a bed of gravel, which passes under the fossiliferous formation at Goodnight. He consequently regards the latter as of later age than the Loup Fork, while he thinks it older than the Equus beds of Rock creek. The paleontology sustains this view."

In July, 1893, I published a paper on the geology of northwest Texas‡ in which I describe the beds under the name of Goodnight division, giving a particular description of the locality, stratigraphic position and the fossils found in the beds. In that paper I said:

"At the mouth of Mulberry cañon, south side, five miles southwest from the town of Goodnight, in the southeastern edge of Armstrong county, there are beds containing fossils differing from the other Tertiary fossils of the Staked plains, and I have called them Goodnight beds for the purpose of referring to them more definitely."

This ought to have been sufficient to fix the name of the beds if they are to be kept up as a separate division.

In the Bulletin of the Geological Society of America, vol. v, 1894, page 94, there is an abstract of a paper by Prof. W. B. Scott, "The later lacustrine formations of the West." In that paper it is said:

"The latest of the three horizons of the Loup Fork may be called the Palo Duro, Cope having found it near the cañon of that name in Texas."

This paper was published on April 30, 1894, at least nine months after the publication of my description under the name of Goodnight division.

In the fourth edition of Dana's Manual of Geology (1895), on page 884, in a "Table of the Approximate Equivalency of the Sub-divisions of the Tertiary," the name Palo Duro is used for these beds. Again, on page 885, it is used: "Palo Duro beds of Scott; Goodnight beds of Cummins, observed near the cañon Palo Duro, in Texas, and also in northern Kansas." Again, on page 919, the name Palo Duro beds is

*Second Annual Report Texas Geological Survey, p. 431.

† Fourth Annual Report Texas Geological Survey.

‡Fourth Annual Report Texas Geological Survey.

used. It is said, also, on page 919, "The preceding list of genera has been prepared for this place for the most part by W. B. Scott."

It will be readily seen from the above quotations that by the right of priority, the name Palo Duro cannot be used for these beds, for I had already described them under the name Goodnight division; I found the beds, collected the fossils, and gave the name to beds occupying a definite horizon with sufficient particularity for identification. All this was done months before the name Palo Duro was suggested by Prof. Scott, who has never been at the type locality, has never seen any of the fossils from there unless he saw those I collected, nor has he ever given a description of the strata composing the divisions, nor has he given a definite description of the locality of the beds.

There are several other errors in Prof. Scott's paper. The fossils were not found by Cope, they are not Loup Fork. They were not found near Palo Duro cañon. The fossils were found by myself. The beds are above the Loup Fork. They do not occur on Palo Duro cañon, but on Mulberry cañon, which is not even a branch of the Palo Duro, and the beds described, so far as known, do not occur within ten miles of any part of Palo Duro cañon, and it would be a misnomer to call them by that name. The name Palo Duro for these beds must give place to Goodnight, the one first used by myself in describing them, notwithstanding the fact that the attempt has been made to substitute one for the other in the "Manual of Geology" by Dana. If priority is not to control then utmost confusion will be the result. W. F. Cummins.

Geological Survey of Texas.

Stages of Recession of the North American Ice-Sheet shown by Glacial Lakes. During the past year this magazine and the American Journal of Science have presented numerous papers by Mr. F. B. Taylor and Prof. J. W. Spencer, describing the evidences of Pleistocene bodies of water in the basins of the great Laurentian lakes, marked by ancient shore lines from near the present lake levels up to maximum hights of 500 to 600 feet or more. The extensive submergence, following the period of deposition of the boulder-clay or till, is ascribed by these authors to depression of the St. Lawrence drainage area so low as to admit the sea to the limits defined by the highest beaches. The alternative view, which attributes the Pleistocene shore lines to lakes dammed on the north and northeast by the receding ice-sheet, is held by Gilbert, Chamberlin, Leverett, and others, including the present writer; but it has had scanty advocacy in the American Geologist while these articles by Taylor and Spencer have been appearing. Another recent writer, Prof. A. C. Lawson, from his examination of the shore lines about the north side of lake Superior, concludes that they were formed by a lake; but he supposes its existence to have been due to land barriers, not to the waning ice-sheet. In the American Journal of Science, however, for last January, I have endeavored to give a summary of the evidence for the origin of all the ancient high shores about the Laurentian lakes by the obstruction of the continental glacier dur-

ing its departure in the closing or Champlain epoch of the Ice age, with citations of the voluminous literature of this subject. The map which accompanied that paper is reprinted in the May AMERICAN GEOLOGIST as Plate X, delineating provisionally seven stages of the ice-sheet, from its maximum extent to the time, late in the process of the ice departure, when the sea appears first to have found an avenue of inflow to the St. Lawrence and Ottawa valleys and the basin of lake Champlain by the melting away of the glacial barrier across the present course of the St. Lawrence in the vicinity of Quebec or farther northeast. The high Pleistocene shores from lake Superior to lake Ontario, and the highest shores above the marine beds eastward, seem to me to be clearly referable to glacial lakes; and for comparison with the opinions of Spencer, Taylor, and Lawson, the sequence of events represented in Plate X by the seven stages of culminating and waning glaciation is here brought very concisely into review.

1. Greatest extension of the ice-sheet; Mt. Washington and the Green and Adirondack mountains enveloped to their summits by the continental glacier; its surface thence rising northward across the St. Lawrence valley to the Laurentian highlands. The Kansan stage of Chamberlin's classification (third edition of the Great Ice Age, 1894, and Journal of Geology, vol. III, pp. 270-277, April-May, 1895).

2. Boundary of the waning ice-sheet at the Altamont moraine, the earliest and outermost of the series traced across the northern United States, marking pauses or slight readvances which interrupted the general glacial retreat. This time, coming after Chamberlin's intervening Aftonian and Iowan stages, was at the beginning of his Wisconsin or moraine-forming stage.

3. Maximum area of the Western Superior glacial lake, 500 to 600 feet above the west part of lake Superior, with outlet through northwestern Wisconsin by the Bois Brulé and St. Croix rivers. The glacial lake Warren, outflowing past Chicago, reached north along the greater part of the basin of lake Michigan; and the Western Erie glacial lake outflowed past Ft. Wayne to the Wabash river.

4. Maximum area of lake Warren, 400 to 600 feet above lake Superior and the north part of lake Huron and Georgian bay; extending east somewhat beyond lake Nipissing, and to Crittenden in southwestern New York, with shores now raised by differential uplift nearly 300 feet above the east end of lake Erie.

5. Boundary of the ice-sheet passing east of lake Nipissing, thence south to the vicinity of Toronto, and east along the north side of the Mohawk river. The glacial lake Algonquin, held by an ice barrier only at the lowest passes east of Georgian bay, with outflow south by the St. Clair and Detroit rivers, was at first tributary to the very short-lived glacial lake Lundy, above the east part of the present lake Erie, but later to the glacial lake Iroquois by the Niagara river, which then began its existence and the erosion of the gorge below its receding waterfall.

6. Recession of the ice-sheet past the north side of the Adirondacks;

lakes Iroquois and Hudson-Champlain thus merged in the glacial lake St. Lawrence, which had a level about 250 feet below lake Iroquois and about 50 feet above the sea.

7. Rapid melting of the border of the ice-sheet by the laving action of the lake St. Lawrence on the west and of the sea in the gulf of St. Lawrence on the east, finally cut through the ice-barrier, permitting the sea to come into the moderately depressed St. Lawrence, Ottawa and Champlain valleys, its southwestern limit being at the Thousand Islands, below the mouth of lake Ontario.

Prof. C. H. Hitchcock, in the May number of the AMERICAN GEOLOGIST (pages 330–335), cites abundant proofs of the transportation of drift from northwest to southeast across the highest mountains of New England, which could have resulted only from the accumulation of the ice-sheet so thick as to fill the St. Lawrence valley and to have greater altitude there and on the Laurentide highlands than on the mountain region south of the St. Lawrence. Eastward the ice had a lobate border, with one lobe covering New Brunswick and Nova Scotia, while another extended from Labrador southeasterly over Newfoundland to the Grand Bank. An intervening tract, reaching northwesterly into the ice-sheet at least to the Magdalen islands, was exempted from glaciation.*

Rain storms, sweeping northeasterly as now over the same region, melted away the southwestern border of the ice-sheet and caused it to recede chiefly from southwest to northeast; but farther eastward, when the storms within a half day, more or less, had advanced to distances of 100 to 200 miles upon the ice-sheet, their precipitation was doubtless changed to snow, causing the ice there to increase in thickness, and transferring the summit of the ice covering the St. Lawrence valley gradually farther and farther to the northeast. It seems thus very probable that the ice may have remained latest as a barrier across this valley even as far northeastward as Metis, nearly 200 miles below Quebec, which I think to be indicated by the glacial striæ as these are described by Mr. Robert Chalmers.† The same predominantly southwestward striation extends thence along the St. Lawrence valley, lakes Ontario and Erie, and onward to southern Illinois. Throughout this distance of more than 1,200 miles the glacial recession, as shown by the striæ, was from southwest to northeast, and the barrier of ice holding the Laurentian glacial lakes was melted back from Chicago to Quebec, or perhaps even to the lower part of the present St. Lawrence estuary, previous to any opportunity for the sea to come into the valley.

More than twenty years ago, Profs. N. H. Winchell and J. S. Newberry referred the Late Glacial submergence in the basins of the Red river of the North and the river St. Lawrence to lakes held by the departing ice-sheet. Their opinion is well sustained, as the present writer believes, by the observations which have since been gathered in more

*Geological Survey of Canada, Report of Progress for 1879-80, Part G. AMERICAN GEOLOGIST, vol. XV, pp. 198, 203, March, 1895.

†Am. Journal of Science, III, vol. XLIX, pp. 273-275, April, 1895.

extended mapping of the old shores and in determinations of their altitudes and changes of level. Traces of other ice-dammed lakes have been also carefully studied in New Hampshire, New Jersey, New York, the Ohio valley, and the Souris valley in North Dakota and Manitoba. Such lakes are also recorded by the Parallel Roads of Glen Roy, and by high beach lines in the valleys on the east side of the Scandinavian mountains. No marine fossils occur in the beaches or other contemporaneous deposits; but fresh-water molluscan shells are found in these deposits within the area of lake Agassiz, which occupied the basin of the Red river and of the Manitoba lakes, and in the beaches and deltas of lakes Warren, Algonquin and Iroquois. These bodies of water are thus proved to have been lacustrine; and the differential inclinations of their shores demonstrate that no land barriers, but only the receding ice, could have confined them on their north and northeast sides.

WARREN UPHAM.

119 Oakdale Ave., Cleveland, Ohio, May 15th, 1895.

PERSONAL AND SCIENTIFIC NEWS.

THE GEOLOGICAL SOCIETY OF WASHINGTON has recently issued a pamphlet of 46 pages which contains the presidential address of C. D. Walcott, entitled "The United States Geological Survey," and abstracts of minutes and lists of officers and members, 1893-1894. It is edited by the secretaries, Whitman Cross and J. S. Diller. The total membership is 156, of which 120 are active and 36 corresponding members.

THE MUSEUM OF COMPARATIVE ZOÖLOGY, Cambridge, Mass., has undertaken to publish, as one volume of its 4to memoirs, a monograph of "The North American Crinoidea Camerata," by Charles Wachsmuth and Frank Springer. As is well known, the authors have devoted years of careful work to the preparation of this monograph, which is expected from the press during the early part of 1896. The volume will contain 600 to 700 pages of text, and will be accompanied by an atlas of 83 plates. As the edition of so elaborate a publication must naturally be limited, subscriptions are asked for at an early date. The subscription price is thirty dollars.

A LIFE OF LOUIS AGASSIZ, by Jules Marcou, will soon be issued from the press of Macmillan & Co. The work will be in two volumes, 8vo, with illustrations. The author had opportunity to know Agassiz intimately, both in Europe and in America.

THE WALKER PRIZE, given by the Boston Society of Natural History, has been this year awarded to Dr. E. W. Claypole of Buchtel College. Akron, Ohio, for an essay on the Devonian formations of the Ohio basin.

THE UNIVERSITY OF KANSAS has recently distributed the following statement concerning a geological survey of the state:

In conformity with the law under which the University of Kansas is now working, the Board of Regents, at a recent meeting, formally organized the University Geological Survey of Kansas, with Chancellor F. H. Snow, ex-officio director; professor S. W. Williston, paleontologist; professor Erasmus Haworth, geologist and mineralogist, and professor E. H. S. Bailey, chemist.

In addition to these, other members of the university faculty will be engaged upon the work of the survey, as well as the advanced students of the departments of geology and paleontology. An effort will also be made to centralize and unify the energies of different geologists in the state who have been doing valuable work along different lines of geological investigations. Already a considerable start has been made and the co-operation of different geologists of the state has been secured.

The policy of the survey will be conservative, with the expectation that it will be continued and eventually include all other branches of the natural history of the state. The general stratigraphy of the state will first be elaborated in order that it may be used in the further study of various questions of economic and scientific importance, all of which will be taken up as rapidly as existing conditions from time to time will permit.

Work in the Coal Measures of the state has been in progress for two summers, and volume I of the report is now almost ready for publication. Other volumes will appear at irregular intervals. Those already under preparation are; one on coal, oil and gas; one on the vertebrate paleontology of the state; and one on the salt and gypsum deposits of Kansas.

AN IMPROVED ROCK CUTTER AND TRIMMER is described by Mr. Edgar Kidwell in the American Journal of Science for May. This machine is quite simple in construction and has been used by the Michigan Geological Survey during the last year with good results. It can be obtained from Merrill Brothers, 465 Kent Ave., Brooklyn, N. Y.

MR. T. C. HOPKINS, formerly of the Arkansas Geological Survey, has been appointed assistant geologist in Indiana. He, together with Mr. Blatchy, state geologist, expects to spend the coming field season working up the building stones of the Carboniferous.

AN ATLAS OF THE STATE OF NEW YORK will be published in a few weeks by Julius Bien & Co. Among other features it will contain temperature, rainfall, and hypsometric maps of the state.

DR. J. G. NORWOOD, Emeritus Professor of Physics in the University of Missouri, died May 6th, in his eighty-eighth year. He is well known to western geologists through his reports which accompany the "Report of a Geological Survey of Wisconsin, Iowa and Minnesota," by Dr. D. D. Owen. In a future number we expect to present a sketch of Dr. Norwood's life, written by Prof. G. C. Broadhead.

INDEX TO VOL. XV.